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THE PHILIPPINE JOURNAL OF SCIENCE

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CITRUS-CANKER CONTROL EXPERIMENTS IN JAPAN

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and

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FOUR PLATES AND ONE TEXT FIGURE

INTRODUCTION

A previous progress report has been presented by the first mentioned of the present writers,(4) in which experiments on the control of citrus canker in the Philippines were described. The conclusions from this report were briefly: That the feasibility of control varied widely according to the different susceptibilities of the citrus species and varieties as hosts. The American-grown grapefruit [*Citrus maxima* (*decumana*)] and West Indian lime (*Citrus aurantifolia*) in the Philippines were

[1] Appreciation is herein expressed to Mr. Gojuhachi Sakai, the owner of the experimental orchard, for considerable assistance throughout the experiments. The writers were also fortunate in having the active collaboration of Mr. Tetsuma Kondo, entomologist of the Nagasaki Ken Agricultural Experiment Station, in connection with the closely related insect problems. Sincere thanks are also expressed to Dr. Carl P. Hartley, of the Instituut voor Plantenziekte, Buitenzorg, for considerable aid as well as suggestions at the time of harvesting the fruits.

The experimental data presented here were obtained while the writers were connected with the United States Department of Agriculture and Nagasaki Agricultural Experiment Station, respectively.

so susceptible to canker as to be very difficult of control; the control of citrus canker on such hosts was not economically feasible in humid climates, by the methods employed. Control had been effected upon the class of citrus varieties of the general susceptibility of the East Indian pummelo (*Citrus maxima*), Washington navel orange (*Citrus sinensis*), and other sweet oranges of Florida origin; however, the feasibility of control from a commercial viewpoint was undetermined. A class of varieties that showed still less susceptibility consisted of the sweet oranges of the Mediterranean group (*Citrus sinensis*), such as the Jaffa, Du Roi, Mediterranean Sweet; some of the American-grown lemon varieties (*Citrus limonia*), the Tahiti lime (*Citrus aurantifolia*), and the Unshiu (Satsuma) orange varieties (*Citrus nobilis* var. *unshiu*). In the Philippines control on such varieties was so readily obtained that its commercial feasibility seemed very probable. The calamondin (*Citrus mitis*), the mandarin orange (*Citrus nobilis* var. *deliciosa*), the round kumquat (*Fortunella japonica*), and some of the citrons (*Citrus medica*) constituted a class of citrus varieties of such slight susceptibility to canker that control measures upon them were unnecessary.

It seemed desirable to try further control measures on an orchard planted exclusively to a variety of the same degree of susceptibility as the Washington navel; this class contains many of the commercially grown varieties, and it seemed important to determine the feasibility of such measures from a standpoint of costs on such a class of hosts. Such further experiments were, therefore, undertaken in an orchard of the Washington navel variety at Saigomura, Nagasaki Prefecture, on Kyushiu Island in southern Japan.

CLIMATIC CONDITIONS IN NAGASAKI PREFECTURE

Temperature, humidity, rainfall, and wind velocity and direction were recorded at the orchard during the actual operations of the experiment. However, to obtain a proper idea of the seasonal conditions, extracts will be presented here from weather data for a five-year period, collected by the Nagasaki Agricultural Experiment Station. The temperature data are shown first, in Table 1.

From Table 1 it can be seen that there is a winter season from early November until the end of April, during which the temperatures are, with a few exceptions, below 20° C. Although the minimum temperature for the growth of the canker organism

in culture is about 5° C. according to Peltier,(5) the minimum temperature for infection and development of the disease upon calamondin (*Citrus mitis*) and grapefruit (*Citrus maxima*) is 20° C. This may be taken roughly as an index of the action on the Washington navel orange (*Citrus sinensis*); according to this, then, canker activity from November until the end of April is negligible or entirely absent.

During this period also the rainfall is not heavy and the canker organism is not disseminated seriously. Although in May the rainfall is slightly increased and the temperatures are slightly higher, it may probably be classed with November to April, as a month of canker inactivity in Japan. The rainfall for the year is shown in Table 2.

Table 2 shows a very decided increase in rainfall for June and early July. The Japanese in Nagasaki claim that there are twenty-one days of continuous rainfall always at this season, and the season is called the *nyubei.* Although the definite period of twenty-one days may be doubted, there is a period of from three to four weeks at this time when there is heavy and intense rainfall; this is accompanied by a very perceptible rise in temperature. After the nyubei, there is a period of little rainfall which, in usual years, constitutes almost a dry season. This lasts through July and early August, sometimes to the end of August. During August and September, however, typhoons sometimes are recorded and these, although irregular in occurrence, must be prepared for. The rains accompanying typhoons raise the rainfall total for these months well above that for July and early August. After the September typhoons October is a comparatively dry and cool month.

It was pointed out previously by the first mentioned of the present writers that canker dissemination is largely dependent upon free moisture, rain or dew, on the foliage. As previously mentioned, Peltier has shown that canker infection is dependent on temperature also, varying according to the host, but safely at 20° C. or above. With these factors, rainfall and temperature, in view, it is apparent that usually there are but two periods favorable to canker dissemination and infection in southwestern Japan: (*a*) the period of the nyubei, which may begin any time in early June and extend into July, and (*b*) the period when typhoons may occur, usually from the latter part of August until the end of September. The nyubei is a period of steady, drenching downpours, but with little or no strong wind. The period August and September is not always accompanied

TABLE 1.—*Showing the temperatures at Nagasaki (city) for a five-year period; data from the annual report of the Nagasaki Agricultural Experiment Station for 1917.*

[Numbers indicate degrees centigrade.]

Year.	January.			February.			March.			April.			May.			June.		
	1-10	11-20	21-31	1-10	11-20	21-28	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30
AVERAGE TEMPERATURE.																		
1907	4.4	11.1	6.1	3.4	4.6	9.1	6.6	6.8	12.4	13.4	13.7	15.3	17.0	16.1	18.8	20.8	20.8	22.2
1908	6.9	4.6	4.6	4.6	6.0	3.6	7.8	8.0	8.0	13.3	13.9	15.1	16.6	15.8	18.7	22.0	20.8	21.3
1909	8.9	5.3	5.8	2.7	4.4	7.9	4.5	8.7	10.4	10.0	14.9	14.9	17.6	17.9	19.6	21.1	22.4	21.2
1910	5.6	3.8	7.9	5.6	6.9	6.9	9.2	9.8	11.0	11.4	13.4	15.1	16.2	17.4	19.9	20.4	21.3	21.3
1911	6.0	3.4	5.6	6.2	6.7	12.6	9.6	7.8	11.4	10.5	14.6	16.8	16.3	18.1	17.7	20.1	20.9	22.4
MAXIMUM TEMPERATURE.																		
1907	8.5	15.2	10.7	6.9	9.0	13.5	10.0	11.6	18.0	18.2	18.7	20.7	21.4	20.4	24.2	24.3	24.0	25.7
1908	11.3	11.0	7.7	8.2	10.3	7.5	13.0	12.0	12.4	18.0	19.2	19.9	21.5	20.6	23.3	25.3	24.0	24.6
1909	8.1	8.5	9.3	6.1	8.2	9.9	8.7	13.3	14.3	14.4	20.0	19.8	21.4	22.8	25.0	24.6	25.7	23.4
1910	10.1	7.3	11.4	10.3	10.2	11.3	12.7	14.3	16.0	16.0	18.6	19.9	20.7	22.1	24.7	24.2	25.1	24.6
1911	9.2	5.9	8.5	10.3	10.8	9.1	13.2	12.2	15.8	14.6	19.1	20.8	21.6	22.3	22.2	24.5	25.0	26.6
MINIMUM TEMPERATURE.																		
1907	1.6	7.0	2.4	0.1	1.2	4.6	4.0	4.0	6.5	9.6	8.1	11.3	12.8	11.9	14.4	16.3	18.0	19.3
1908	3.4	3.4	1.5	1.2	1.9	1.0	3.8	5.7	4.0	8.5	9.5	11.3	12.8	7.1	14.5	17.4	17.2	16.9
1909	1.7	2.6	3.6	0.2	1.8	2.8	1.3	5.1	7.3	5.7	9.7	10.5	14.0	13.6	14.8	15.0	19.7	19.0
1910	1.8	0.5	3.9	1.3	3.3	3.2	5.6	6.2	6.2	7.5	9.2	10.4	12.1	13.6	15.8	16.9	12.0	18.3
1911	3.4	1.3	1.9	3.5	3.1	7.6	6.3	4.2	7.6	7.0	9.6	13.2	12.3	14.3	13.9	15.7	22.3	18.5

AVERAGE TEMPERATURE.

Year.	July.			August.			September.			October.			November.			December.		
	1-10	11-20	21-31	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31
1907	21.4	23.8	27.1	26.8	26.3	25.4	25.5	21.6	19.9	13.7	17.2	18.2	14.0	10.5	9.4	9.3	9.3	7.7
1908	22.4	26.9	27.0	27.1	26.6	25.9	25.6	25.6	22.1	18.3	18.7	15.8	15.4	12.5	11.5	8.5	5.8	7.2
1909	23.6	26.3	27.3	26.5	25.5	26.5	25.0	22.0	21.5	18.3	16.2	16.9	14.0	10.5	12.1	6.3	4.6	5.9
1910	23.2	26.2	25.3	25.7	26.8	26.4	25.3	24.9	23.2	19.4	15.6	16.1	13.3	14.9	11.3	8.8	6.8	5.2
1911	22.1	25.3	25.2	26.1	26.2	26.3	25.0	20.7	19.8	17.6	16.1	16.8	13.0	8.9	9.8	7.4	9.9	6.2

MAXIMUM TEMPERATURE.

Year.	July 1-10	July 11-20	July 21-31	Aug. 1-10	Aug. 11-20	Aug. 21-31	Sept. 1-10	Sept. 11-20	Sept. 21-30	Oct. 1-10	Oct. 11-20	Oct. 21-31	Nov. 1-10	Nov. 11-20	Nov. 21-30	Dec. 1-10	Dec. 11-20	Dec. 21-31
1907	23.2	28.1	31.3	32.8	30.6	29.6	30.7	25.6	23.8	22.7	21.3	22.6	17.7	15.1	13.1	18.2	13.7	11.8
1908	26.4	31.0	31.2	27.8	31.0	30.5	30.0	29.5	26.9	22.2	23.8	19.5	19.1	17.3	15.5	12.5	8.5	11.1
1909	27.1	30.5	32.4	31.8	29.6	34.0	29.2	25.7	25.2	22.2	20.8	22.4	18.4	15.1	16.5	8.9	8.1	9.9
1910	26.6	30.1	29.1	29.7	31.0	30.7	26.5	28.7	26.7	22.5	19.6	20.9	17.9	19.1	14.1	12.5	10.5	8.0
1911	25.1	27.4	27.8	30.7	30.7	30.6	28.9	23.5	23.9	21.6	21.1	21.0	16.4	12.9	13.9	11.3	8.8	9.4

MINIMUM TEMPERATURE.

Year.	July 1-10	July 11-20	July 21-31	Aug. 1-10	Aug. 11-20	Aug. 21-31	Sept. 1-10	Sept. 11-20	Sept. 21-30	Oct. 1-10	Oct. 11-20	Oct. 21-31	Nov. 1-10	Nov. 11-20	Nov. 21-30	Dec. 1-10	Dec. 11-20	Dec. 21-31
1907	18.8	20.5	24.9	21.3	23.1	21.9	21.6	19.3	17.0	15.3	12.8	15.2	10.8	5.8	6.2	6.5	5.8	4.4
1908	20.9	23.5	23.3	23.8	23.6	22.7	22.6	22.5	19.3	14.9	14.7	12.0	11.9	8.8	7.8	5.0	2.0	3.7
1909	21.2	23.3	23.3	23.8	22.0	23.0	22.2	18.7	23.8	15.4	12.8	13.7	10.6	7.3	8.5	3.5	1.4	2.8
1910	20.5	23.1	22.0	21.9	23.2	23.2	20.6	22.0	22.0	16.5	12.1	10.4	9.2	11.2	8.1	6.5	3.3	2.8
1911	13.9	23.5	22.9	23.7	22.7	22.5	20.8	17.4	16.0	13.8	11.6	13.6	10.1	5.7	7.8	3.9	6.4	3.0

TABLE 2.—*Showing the precipitation in millimeters at Nagasaki for a fifteen-year period; data from the annual report of the Nagasaki Agricultural Experiment Station for 1917.*

Year.	January.			February.			March.			April.			May.			June.		
	1-10	11-20	21-31	1-10	11-20	21-28	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30
1897	70.8	7.8	56.9	38.4	18.6	88.6	7.8	20.1	84.5	25.7	21.0	9.0	86.9	133.1	84.0	130.4	37.9	44.0
1898	10.8	4.5	26.7	8.3	43.8	114.4	51.0	30.6	45.9	13.8	102.0	41.6	89.9	46.8	21.3	161.1	85.8	109.2
1899	11.5	18.9	31.1	17.9	4.9	....	12.6	21.5	36.2	93.6	149.7	88.1	89.1	66.8	95.2	10.6	19.3	55.8
1900	18.4	33.9	55.4	12.8	81.2	13.8	47.5	5.6	12.8	44.3	99.0	17.3	50.0	18.0	40.4	95.0	15.3	436.4
1901	8.8	4.3	38.3	17.9	11.7	32.6	27.4	12.8	120.5	102.4	43.9	109.2	180.3	89.9	41.4	49.4	123.8	31,1
1902	23.5	27.6	72.7	25.0	24.5	40.1	19.8	56.5	36.4	11.2	202.2	244.5	29.6	194.2	48.7	86.1	8.9	17.7
1903	1.2	38.5	6.7	15.3	20.1	25.4	86.0	17.7	23.1	53.6	55.5	136.7	23.4	27.5	61.8	15.7	114.2	17.7
1904	27.7	23.7	28.3	15.2	12.8	55.6	23.3	79.5	70.2	4.8	129.7	56.5	79.6	23.2	49.8	147.7	134.8	112.4
1905	89.9	34.3	18.7	49.3	19.7	65.4	15.6	42.4	66.1	19.0	3.9	31.7	67.7	154.8	76.2	87.0	118.4	145.6
1906	4.8	21.1	56.1	52.5	12.9	2.9	28.2	23.5	72.8	88.0	46.9	28.1	136.0	14.2	29.5	58.0	158.0	38.2
1907	4.5	17.5	2.7	13.4	0.4	5.2	30.6	18.9	9.6	161.9	58.5	68.5	32.4	75.4	19.0	6.4	54.8	183.4
1908	11.6	30.2	25.7	15.3	54.0	3.1	58.5	64.1	71.6	85.8	75.0	43.7	87.1	20.2	13.4	66.2	67.0	238.6
1909	63.6	81.8	20.4	18.6	18.4	24.9	11.8	40.2	100.8	74.2	16.2	124.5	69.1	16.6	5.9	21.8	247.4	149.2
1910	38.6	3.1	53.0	2.5	33.5	5.3	120.6	65.0	44.3	84.8	30.8	45.9	39.1	41.8	85.7	72.1	256.8	189.4
1911	40.0	3.4	21.7	17.6	32.1	140.2	51.3	11.7	109.4	72,2	1.9	106.4	32.1	27.0	9.4	67.5	133.8	20.9
Average	25.0	23.3	36.3	21.3	22.5	40.8	39.5	34.0	60.9	59.0	68.7	74.1	65.5	63.8	40.2	71.7	105.7	141.4

Year.	July.			August.			September.			October.			November.			December.		
	1-10	11-20	21-31	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31
1897	62.3	0.1	103.4	18.0	101.7	77.4	19.2	36.2	47.7	42.4	13.8	6.1	21.1	62.1	79.7	13.9	38.7	85.8
1898	14.9	30.7	44.8	48.7	239.0	32.9	68.3	75.3	13.9	1.4	51.0	18.5	27.0	53.6	4.1	2.2	63.6	56.3
1899	528.8	216.4	1.6	12.4	54.7	102.0	156.9	9.6	22.2	71.0	71.6	18.4	39.4	45.1	53.9	28.2	8.6	4.2
1900	187.7	221.8	45.3	25.0	83.6	5.2	9.3	66.0	0.4	180.1	8.0	7.4	3.7	35.8	3.6	11.5	8.6	12.2
1901	29.7	71.0	87.8	100.2	118.6	52.7	112.6	0.1	63.6	0.1	43.8	87.6	44.2	6.9	45.7	37.2	27.6	33.6
1902	92.1	238.9	76.3	45.4	1.5	13.9	3.2	145.9	8.5	55.9	8.4	31.5	14.2	12.5	27.5	25.0	36.7	6.8
1903	11.8	17.4	28.9	7.6	64.9	1.5	36.1	35.5	2.0	9.7	35.6	8.9	3.9	65.6	7.7	5.8	20.8	21.1
1904	82.1	174.4	186.9	87.0	221.7	175.1	97.8	9.5	8.5	11.5	41.9	87.4	34.0	10.9	0.6	14.5	37.3	95.4
1905	29.9	47.4	7.2	72.9	60.4	3.0	251.2	89.1	23.6	76.1	3.4	70.4	1.0	13.9	6.4	19.3	31.0	22.9
1906	186.4	95.3	1.6	49.4	3.1	0.4	127.0	21.3	104.3	34.6	83.2	8.0	10.5	41.5	81.1	30.9	4.1	9.5
1907	168.4	67.5	4.4	34.5	57.0	67.2	-------	79.2	66.5	81.8	79.4	20.9	16.9	3.2	0.5	1.7	31.3	48.4
1908	188.5	20.7	43.1	57.2	89.3	17.2	104.4	305.3	79.3	11.1	15.1	70.5	40.1	-------	22.3	10.8	10.9	54.1
1909	85.3	13.1	8.9	14.4	22.0	93.1	390.6	51.0	10.4	59.6	57.8	-------	76.0	15.2	35.3	4.2	6.7	15.4
1910	61.9	2.1	154.8	57.1	9.1	52.3	250.1	136.5	71.0	98.7	6.5	1.1	19.4	45.5	88.7	30.0	14.2	33.7
1911	214.4	133.6	224.1	4.9	2.1	28.8	67.5	109.1	11.3	57.1	3.8	55.7	21.1	88.5	2.9	20.3	41.6	46.7
Average	129.6	90.0	67.9	42.3	75.2	68.2	112.9	78.0	35.5	49.4	34.9	32.5	24.8	29.9	27.3	17.0	25.1	33.0

by typhoons; but, when such storms occur, the winds are usually accompanied by rain and conditions are extremely favorable for canker dissemination as well as infection.

The seasons in Nagasaki Prefecture, from the viewpoint of activity for canker dissemination and infection, may be approximately grouped as shown in Table 3.

TABLE 3.—*Showing climatic periods in Nagasaki Prefecture, favorable or unfavorable for citrus-canker development.*

November, December, January, February, March, and April:

Temperatures usually below 20°C. Rainfall slight; canker dissemination and development very slight, if at all active. No foliage or fruit development of host plants during the period November to March.

May:

Temperatures usually below 20°C. and rainfall usually low. No growth of foliage during this period.

June and July:

Temperatures increased and favorable for canker development. Rainfall increased, frequently intense, favorable for canker development. The fruit and foliage of the host plant growing actively and favorable for canker infection.

Late July and early August:

Temperatures favorable for canker development, but rainfall slight; under ordinary seasonal conditions not a period for serious canker development.

August and September:

A period of possible typhoons with high wind velocities and intense rainfall, favorable for the dissemination and development of citrus canker. There is little foliage growth at this time but fruit development is taking place and the fruit tissues are in a susceptible stage.

October and November:

The temperatures become lower very abruptly in usual years; rainfall also is very slight. The fruit is so nearly mature as to be no longer susceptible, and no foliage growth takes place at this season. This is a period in which canker activity may be disregarded.

With this perspective of the seasonal conditions, the control campaign was outlined to apply protective spray coatings during the critical seasons of the nyubei in June and the period of probable typhoons in late August and September; how this was done will be shown in detail in the following pages.

EXPERIMENTAL METHODS AND ORCHARD CONDITIONS

The orchard conditions can best be appreciated by an extract from the writers' notebook written before the experiments were undertaken.

Saigo is in Nagasaki Prefecture in the southern part of Kyushiu Island. The town of Saigo is on the sea while the orchard is about 3 kilometers inland and in the foothills of Mount Unsen; the orchard is at an elevation of about 60 meters above sea level.

The Saigo region is not planted much to oranges. This orchard stands in the foothills, surrounded on the mountain side with scrub pine trees while toward the town are scrub pines with a few barley and soy-bean fields; there are no other orchards near at hand. This orchard is surrounded by several rows of some sort of coniferous tree making a fairly good windbreak on all sides. At the present time (December) the northeast monsoon comes right off the sea and hits the orchard; the force of the wind, however, is somewhat broken by this windbreak.

The orchard consists of about 6 hectares of navel orange trees said to be eighteen years old. The trees are planted on *Citrus trifoliata* stock and are consequently somewhat dwarfed, nevertheless they stand well above a man's head, 2.5 to 4 meters high, and are very broad and compact. They are headed low, in much the same manner as California trees.

The land has a decided slope but not so great that a wagon or sled cannot be pulled in all directions. In some places the orchard is terraced but it will be possible to select plats between such terraces. The orchard has been well cultivated (by hand) and is in fine growing condition. Fertilizers, soy-bean cake, and a fish-product fertilizer are applied abundantly in the spring, according to the owner. He has been bothered considerably by the fruits becoming badly blemished by canker and would welcome anything which would prevent the trouble.

An idea of the size and character of the trees and the state of cultivation of the orchard may be obtained from a photograph of the orchard shown in Plate 1.

The arrangement of the experimental plats is shown in fig. 1.

The pruning indicated in plats 1, 2, 3, 4, and 5 in fig. 1 was extremely careful, an effort being made to eliminate all cankers or at least to reduce them to but a few. As much as three hours were sometimes spent to a tree. In plats 13, 14, 15, 16, and 17 more rapid pruning was attempted and this was called "rough pruning," by the Japanese. In the case of these plats the sources of infection were greatly reduced, but no attempt was made to eliminate entirely the foliage cankers or to reduce them to but a numerical few.

The cost of these methods of pruning was recorded and is shown in Table 4.

The spray mixtures indicated in fig. 1 are so commonly used as to require little explanation. Lime sulphur at a concentration of 32° Baumé was used in a 1 to 40 dilution with water, unless otherwise noted. Bordeaux 4–4–50 mixture was prepared in the usual way, adding diluted and recently slaked quicklime to a dilute copper sulphate solution; it was used immediately after preparation. Neutral Bordeaux mixture was prepared

by adding the diluted, recently slaked quicklime in just sufficient amount to precipitate entirely all of the copper. Burgundy 3-3-50 mixture was always prepared with diluted constituents and applied immediately after its preparation. Formalin 1 to 100 was always applied immediately after its preparation. Spray solutions and mixtures were applied with a pump operated by hand; the pump was equipped with a pressure gauge and pressure was maintained at from 120 to 140 pounds.

TABLE 4.—*Showing cost of labor employed in removal of sources of infection.*

CAREFUL PRUNING, PLATS 1, 2, 3, 4, AND 5.

Date.	Men.	Hours.	6-hour days.	Cost at Y 1.20 per day.
				Yen.
December 29, 1918	11	66	11	13.20
	2	6	1	1.20
December 30, 1918	8	56	9.3	11.20
	1	3	0.5	0.60
	1	4	0.6	0.80
December 31, 1918	9	36	6	7.20
	8	12	2	2.40
	1	3	0.5	0.60
	6	39	6.5	7.80
January 4, 1919	2	9	1.5	1.80
January 6, 1919	8	64	10.6	12.80
Total		298	49.5	59.60
ROUGH PRUNING, PLATS 13, 14, 15, 16, AND 17.				
December 31, 1918	4	6	1	1.20
January 5, 1919	3	3	0.5	0.60
January 6, 1919	2	1	0.16	0.20
January 7, 1919	3	10	1.66	2.00
	[illegible]	6	1	1.20
Total		26	4.32	5.20

Careful pruning of 100 trees cost 59.60 sen per tree.
Rough pruning of 50 trees cost 10.40 sen per tree.

The dates of field operations follow, in Table 5.

TABLE 5.—*Showing treatment of the experimental plats for citrus-canker control at Saigomura, Japan.*

Plats 1, 2, 3, 4, 5, pruned December 29, 30, and 31, 1918; January 4 and 6, 1919.

Plats 13, 14, 15, 16, 17, pruned December 31, 1918; January 5, 6, and 7, 1919.

First spray application, June 3, 4, 5, and 6, 1919.
Second spray application, June 24, 25, and 26, 1919.
Third spray application, August 24 and 25, 1919.

The pruning listed above being made in early winter the following extracts from the notes in the succeeding May are of interest:

Upon none of the trees, those of untreated plats as well as those of treated plats, was there foliage young enough to be susceptible. All of the trees

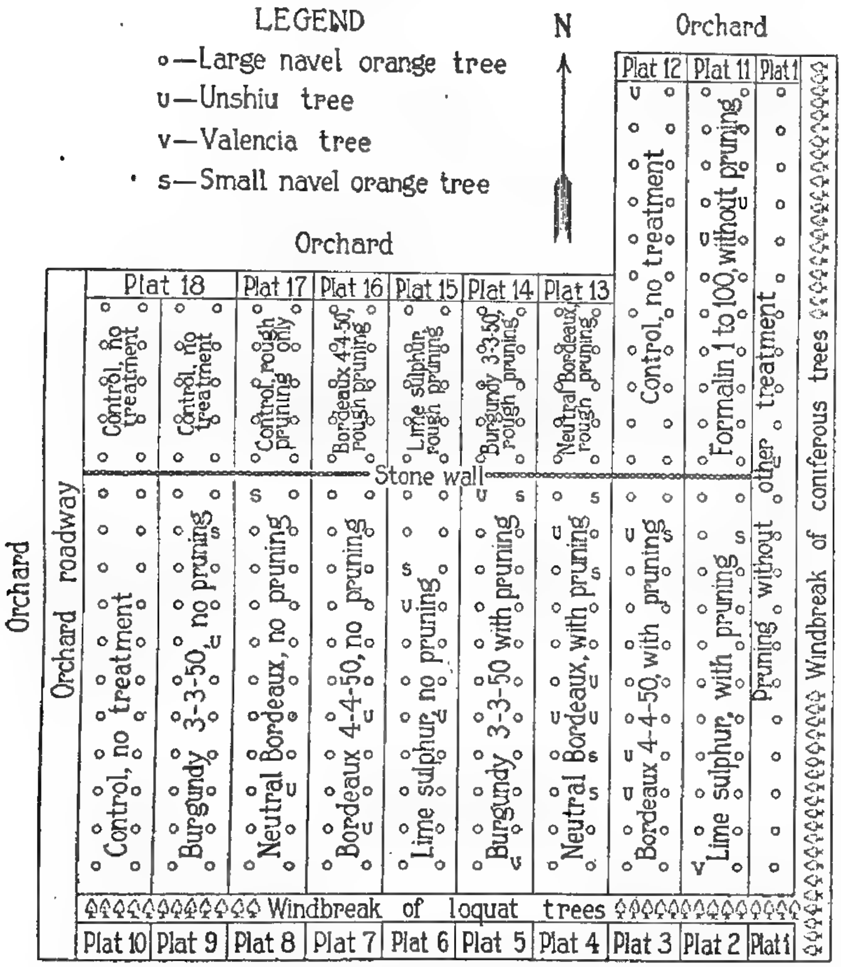

FIG. 1. Showing the arrangement of the experimental plats in the Washington navel orchard at Saigomura, Japan. Plat 19 lies south of the plats shown above.

showed some growth, new since last winter, but this was all well hardened and matured, and considered to be past the stage for development of infection. The pruned plats showed considerably more of this type of foliage than did the untreated plats. All of the trees showed that many of the old leaves had dropped during the winter and the trees were largely foliated with leaves formed since last January. The total amount of foliage of the trees in the pruned plats was appreciably greater than that of the trees in unpruned plats. A considerable drop of the young, newly formed fruits was observable throughout the orchard. Although time did not permit of an actual count, the observations indicated that the fruit drop was considerably less on the pruned plats than on the unpruned plats. Altogether, the general thrift of the pruned plats was very much greater than that of the untreated plats.

The field notes following the second application may also be of interest.

DISCUSSION OF SPRAYING METHODS, SECOND APPLICATION, 1919

Lead arsenate, neutral, was added as a paste, at the rate of 2 pounds for every 50 gallons of spray; this was used uniformly throughout all sprayed plats. The purpose was to check the chewing insects which have been very numerous in the past few months. What Mr. Kondo calls blister moth has also been very common, and this was observed last fall to be very active in disseminating canker. It is hoped that the lead arsenate will be a means of checking this dissemination of canker.

Careful examination was made of the trees in the different plats. Several trees in the control plats showed very new cankers. Two trees in the formalin plats showed no foliage or fruit cankers as yet.

On plats 2, 6, and 15 there was a slight leaf fall. These plats were sprayed with lime sulphur (of a density of 25° Baumé) 1 part to 33 parts of water, plus 2 pounds of lead arsenate (neutral paste) to 50 gallons of solution. The mature, well-formed leaves were the ones that dropped, while the young, new, actively growing leaves were apparently not injured. There was no visible lesion of any sort on the fallen leaves. The loss of leaves was not serious, and apparently no well-formed fruits were caused to drop. The trees are at present in a condition in which they need all possible leaf surface and the leaf drop is regrettable from that standpoint.

On the formalin 1 to 100 plat (plat number 11) there was also a slight leaf drop. This plat was sprayed with formalin 1 to 100, plus lead arsenate (neutral paste) in the proportion of 2 pounds to 50 gallons of the mixture. In this case, however, the affected leaves were the young, actively growing, light-colored ones, while the matured leaves showed no ill effects whatsoever. Upon the fallen leaves and upon the young leaves upon the tree, white-colored, killed areas of tissue showed where the formalin mixture had injured the tissue. There were no indications whatsoever of injury on the fruit.

Careful examination of the plats for new cankers was made. On the pruned plats numbers 1, 2, 3, 4, and 5 no new canker lesions were observed. Some new lesions were observed in sprayed but unpruned plats; such lesions were all foliage cankers, however, and no fruit infections were seen. They were, at this time, so few as to cause no alarm. Upon the unsprayed plats, those entirely untreated, considerable amounts of new

foliage infections were to be observed; no infections were observed on the fruits. Three trees of the formalin plat showed a considerable amount of new foliage infections but no fruit infections.

A careful examination was made for indications of an outbreak of ruby scale but no signs were visible at this time. If the scale insects remain as they are, without perceptible increase, the insecticide application planned for the latter part of July will be omitted.

Leaf samples were brought back to Nagasaki and tested for the amounts of copper remaining on the foliage. The test used was the method described by Winston and Fulton: (7) dissolving the copper compounds on the leaves in a dilute nitric acid solution, testing this wash solution with potassium ferrocyanide, and comparing the resulting color formed with the coloration formed in solution having a known copper content. The results were as follows:

Bordeaux 4–4–50 applied June 24; tested July 2, 50 m. g. Cu per 100 grs. of leaves.

Bordeaux neutral applied June 24; tested July 2, 40 m. g. Cu per 100 grs. of leaves.

Burgundy 3–3–50 applied June 25; tested July 2, 40 m. g. Cu per 100 grs. of leaves.

These results should be compared with tests made June 17 on the adherence of copper sprays, as follows:

Bordeaux 4–4–50 applied June 5; tested June 17, 45 m. g. Cu per 100 grs. of leaves.

Burgundy 3–3–50 applied June 6; tested June 17, 40 m. g. Cu per 100 grs. of leaves.

Bordeaux neutral applied June 6; tested June 17, 60 m. g. Cu per 100 grs. of leaves.

Lime sulphur applied June 4; tested June 17, showed no trace of sulphur remaining on any parts of the foliage.

It will be seen that the copper-precipitate sprays adhere very well; but aside from this no conclusions as to their relative adherence are possible at this time.

The following extracts are taken from the field notes made following the third application, August 25, 1919:

In the sprayed and unpruned plats the fruits are for the most part entirely free of canker at this time; there are a few cases, usually in the tops of the trees, where fruits have been badly whipped by nearby branches and where canker has then resulted severely. Such infections are white in color and apparently new; it would seem probable that they are a result of the typhoon on August 16 and 17. At present the Burgundy and neutral Bordeaux plats show up to the best advantage, but such a statement is only an opinion, and substantial results will be obtained only at fruiting time. The lime-sulphur results are decidedly not equal in value to the results from the copper sprays; there are three to five fruits under each tree in the lime-sulphur plat, that fell due to canker infection; and on each tree there is a number of fruits badly cankered. This is a decided contrast to the results on the Burgundy and Bordeaux plats, where a search has to be made to find an infected fruit.

The pruned plats are still in fine condition; there are few or no foliage infections, and not a fruit has been seen to be affected as yet. Apparently the crop is not so heavy, however, on these pruned plats as upon the unpruned plats.

The formalin plat is in much the same condition as are the untreated plats; the fruits fallen from canker infection are scattered around on the ground almost as thickly as is the case with the untreated plats. Many fruits are badly affected on the tree. On this plat it is necessary to hunt for uninfected fruits.

The insect called the blister moth is present in abundance; this is *Phyllocnystis soligna* Zell., according to Kondo. It is a leaf miner and is found throughout the orchard on all young twigs and leaves. It is the most serious of the agents for dissemination of canker; along the trails of this insect, canker always develops heavily, while nearby tissue on which the leaf miner has not operated will be free from canker. The blister moth is very difficult to control, according to Kondo, and he can suggest no remedy.

Extracts from the field notebook continued:

September 9, 1919. Canker developed on some of the sprayed but unpruned plats and to a considerable degree on some of the fruits. Attention was called by the owner to the occurrence of all cankered fruits on the southwest side of the tree while on the northeast side the fruits were free of canker. This was made a point of careful observation and was noted to be true in every case on the sprayed plats. In the case of the controls the cankers were on all sides, but somewhat worse on the southwest side. This is evidence to some extent that infection took place at the time of the typhoons in August, for the wind at that time came from the south and swept across the orchard from the southwest. On the west side of the orchard, within the protection of the windbreak, there is little or no injury of this type but on the eastern side, where the sprayed plats are, there is considerable evidence of wind injury. On many of these trees in the eastern part, twigs can be commonly observed broken off by the force of the wind.

Further evidence that these cankers developed from infection at the time of the typhoon is contained in the data resulting from artificial inoculations on fruits, made under natural conditions.

Artificial inoculations made July 27, 1919, had developed and were well matured on August 25, 1919. Cankers upon the sprayed plats were not visible, except in a few cases, at this time. Inoculations made August 25 have not developed at the present time, whereas there are now a number of cases of infection on fruits in trees on the sprayed plats. Such infection must therefore have taken place between July 27 and August 25.

The weather reports show only two periods during this time in which the climatic conditions were such as to disseminate canker, these periods being during August 2, 3, and 4, a typhoon, and during August 14, 15, and 16, another typhoon. Both of these storms were unexpected and the trees were entirely unprotected by sprays. In the next year, in addition to two applications in June, another application will be made August 1 to safeguard fully the trees against infection which may be made possible by typhoons in August.

Examination was made to observe the effect of the copper sprays in increasing scale insects. Ruby scale was observed to a very slight degree, but not seriously. Some ruby scale was observed upon trees in the lime-sulphur plat, but less than on the other plats. No other scale insects were serious. The blister moth, *Phyllocnystis soligna* Zell., was observed to be equally injurious on all plats. Apparently there was no reduction in the injury from this insect in the lime-sulphur plats; nor is there any evidence to show that the lead arsenate has caused reduction. This insect is the most active agent in disseminating citrus canker in the Japanese orchards.

In the light of future developments it is interesting to note that there were no indications at this time of red spider.

To supplement these field notes, the climatological data collected at the orchard during the experiments are presented here; the temperature and humidity data are contained in Table 6, and the rainfall data, in Table 7.

TABLE 6.—*Showing the temperatures and humidity at the experimental orchard at Saigo during the experiments.*

Date.	Temperature.				Humidity.			
	Absolute maximum.	Absolute minimum.	Mean maximum.	Mean minimum.	Absolute maximum.	Absolute minimum.	Mean maximum.	Mean minimum.
	°C.	*°C.*	*°C.*	*°C.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
June:								
1 to 10	------	------	------	------	100.0	56.8	99.6	68.4
11 to 20	28.9	19.0	27.5	20.6	100.0	66.0	98.0	77.7
21 to 30	28.1	17.5	25.8	19.2	100.0	71.0	97.6	78.7
July:								
1 to 10	29.6	19.0	26.9	21.4	100.0	68.0	98.6	80.8
11 to 20	32.2	20.6	30.2	22.6	100.0	50.1	98.7	70.8
21 to 31	32.5	22.8	33.1	23.4	100.0	65.0	98.5	72.5
August:								
1 to 10	32.8	20.5	30.4	22.7	100.0	64.0	98.9	71.8
11 to 20	33.0	21.0	30.4	23.2	100.0	51.1	97.2	70.1
21 to 31	32.9	20.5	31.0	22.7	99.2	59.5	97.6	68.9
September:								
1 to 10	32.9	19.8	29.2	22.5	100.0	59.0	96.7	72.5
11 to 20	28.0	18.0	25.9	19.5	99.5	62.5	94.8	74.0
21 to 30	28.0	16.5	26.2	17.9	100.0	40.0	98.0	64.8
October:								
1 to 10	79.3	58.0	75.4	62.5	100.0	57.1	98.4	74.4
11 to 20	75.3	51.6	71.6	55.7	100.0	62.0	95.0	71.4
21 to 31	74.0	49.0	66.5	53.3	100.0	39.5	98.0	66.4
November:								
1 to 10	68.0	52.5	65.0	54.7	100.0	67.0	96.1	77.1
11 to 20	65.2	42.0	60.4	47.8	100.0	52.5	94.6	67.8
21 to 30	58.9	37.9	54.9	42.2	100.0	56.5	97.6	64.8

These tables are of interest in indicating the periods at which infection was most active. It seemed apparent, as is recorded

TABLE 7.—*Daily rainfall in millimeters at the experimental citrus orchard, Saigo, Japan, during the fruiting season of 1919.*[a]

June.			July.			August.			September.			October.			November.		
1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-31	1-10	11-20	21-30	1 10	11-20	21-31	1-10	11-20	21-30
----------	3.0	2.2	35.0	3.2	0.0	----------	----------	----------	9.7	----------	----------	0.5	----------	----------	----------	----------	1.1
----------	14.4	25.4	42.5	1.9	3.6	5.2	----------	0.4	0.2	----------	----------	----------	17.5	----------	----------	----------	.2
----------	45.9	----------	40.1	0.0	0.0	34.1	----------	6.4	----------	----------	----------	2.5	1.7	----------	17.9	----------	----------
----------	----------	0.7	57.9	0.0	9.2	28.4	1.5	----------	26.3	3.2	----------	4.0	----------	----------	12.5	4.0	----------
----------	29.8	6.7	30.4	0.0	0.0	1.1	21.2	2.8	5.9	0.2	----------	7.2	----------	----------	1.0	----------	1.0
----------	12.8	11.3	17.4	0.0	0.9	----------	17.6	0.1	0.2	----------	----------	----------	----------	----------	.0.1	----------	0.1
5.0	----------	0.3	24.2	0.0	0.0	----------	0.4	----------	----------	----------	----------	0.2	----------	----------	----------	11.6	----------
3.1	0.2	5.7	0.9	15.6	0.0	----------	----------	----------	2.9	----------	----------	----------	----------	----------	1.2	3.2	----------
3.7	1.3	----------	0.0	0.0	0.0	----------	----------	----------	16.9	----------	20.9	0.2	----------	----------	0.1	0.8	----------
----------	----------	----------	2.8	0.0	0.3	----------	----------	----------	0.1	----------	----------	0.1	----------	4.3	----------	0.1	----------
----------	----------	----------	----------	----------	2.5	----------	----------	----------	----------	----------	----------	----------	----------	11.4	----------	----------	----------
11.8	107.4	53.3	251.2	25.7	16.5	68.8	40.7	9.7	72.4	3.4	20.9	14.7	19.2	15.7	32.8	19.8	2.4

[a] Figures in boldface indicate periods of typhoons.

in the field notes, that in the plats sprayed with Bordeaux and Burgundy mixtures, there was little increase in canker resulting from the nyubei. Although there was a slight canker increase on the lime-sulphur plats following the nyubei, it was not extensive. Basing the spraying campaign upon the weather reports for fifteen years, collected in Nagasaki Ken, no spray applications were planned following the nyubei, in late July or early August, since typhoons usually did not occur until later. In following this plan the experiments suffered, as Tables 6 and 7 indicate. On August 2, 3, 4, and 5 a typhoon occurred, and a violent southwest wind swept the orchard, accompanied by rain. On August 14, 15, 16, and 17 another typhoon swept across southern Japan, with another rainstorm and violent southwest winds striking the orchard. Both of these typhoons occurred at a time when the trees were entirely unprotected by spray coatings. The experiments were therefore unfortunate in this one way, in that the mean seasonal conditions did not occur.

EXPERIMENTAL RESULTS

The effect of the various treatments upon the plats was measured by the number of fruits free of canker. Citrus canker except on the extremely susceptible hosts, the American grapefruit and West Indian lime varieties, is primarily a fruit blemish. The limbs and twigs are not seriously attacked, and the foliage infection is no more serious than citrus scab. By determining the number of fruits affected, therefore, the commercial value of the treatments is very closely determined. Moreover, the data thus obtained for the control plats constitute probably the most-definite measurement of the commercial losses, due to citrus canker, so far obtained.

The results from the various treatments are shown in Table 8.

From Table 8 it is evident that (*a*) all of the spray mixtures except formalin have reduced citrus-canker infection; (*b*) the Bordeaux mixtures apparently caused greatest reduction in citrus canker; there are not sufficient data to form any conclusion as to which is the better of the two mixtures employed; (*c*) Burgundy mixtures, although producing substantial reductions in the amount of canker, in no case equaled the Bordeaux mixtures in this regard; (*d*) formalin was the least effective of the sprays employed and was entirely without value; (*e*) lime sulphur reduced citrus-canker infection materially, but in no case to the extent that the copper sprays did; lime sulphur, however, had other advantages, as will be described later; (*f*) the very care-

ful pruning also materially reduced citrus canker in all cases; (*g*) the procedure which the Japanese called "rough pruning" is shown to have reduced citrus canker slightly; (*h*) the freedom from canker of the fruits on plats treated by both pruning and spraying is such as to warrant the statement that a substantial control was obtained.

TABLE 8.—*The effect of the control treatments on the presence of citrus canker.*

Plat No.	Treatment.	Fruits.	Trees.	Average fruits per tree.	Fruits free of canker.	Fruits cankered.
					Per cent.	*Per cent.*
1	Canker removed by pruning; no spraying	2,382	20	119.1	55.12	44.88
2	Canker removed by pruning; lime sulphur 1-40	2,692	21	128.1	66.59	33.41
3	Canker removed by pruning; Bordeaux mixture 4-4-50.	2,525	18	140.3	90.07	9.22
4	Canker removed by pruning; Bordeaux mixture, neutral.	1,169	16	73	93.58	6.42
5	Canker removed by pruning; Burgundy mixture.	1,712	20	85.6	81.48	18.62
6	No pruning; lime sulphur 1-40	2,668	19	140.4	22.75	77.25
7	No pruning; Bordeaux mixture 4-4-50	3,389	20	169.4	62.86	37.14
8	No pruning; Bordeaux mixture, neutral	2,963	21	140.2	65.40	34.60
9	No pruning; Burgundy mixture	3,256	20	162.8	53.40	46.60
10	No pruning; no spraying; control	4,601	22	209.3	14.17	85.83
11	No pruning; formalin 1-100	2,863	20	247.1	3.86	96.14
12	No pruning; no spraying; control	2,487	21	118.5	3.25	96.75
13	Rough pruning; Bordeaux mixture, neutral	695	9	77	70.36	29.64
14	Rough pruning; Burgundy mixture	1,224	9	136	60.38	39.62
15	Rough pruning; lime sulphur	974	10	97.4	51.75	48.25
16	Rough pruning; Bordeaux mixture 4-4-50	1,299	10	129.9	71.97	28.03
17	Rough pruning; no spraying; control	1,329	10	132.9	34.84	65.16
18	No pruning; no spraying; control	2,271	18	126.3	19.28	80.72
19	Do	524	20	26.2	7.25	92.75

In a previous paper(3) the senior writer advanced the conclusion, among others obtained by modifications of the phenol-coefficient tests, that in culture tubes copper sprays were inefficient as bactericides for *Pseudomonas citri* unless the copper precipitant was added to excess. It is interesting to observe that M. and Mme. Villedieu(6) have advanced conclusions in close agreement with this, working upon *Phytophthora infestans* in France. The present results indicate that, although copper-precipitate mixtures as used in vitro in the phenol-coefficient tests were inefficient as bactericides, the real criterion, the tests as preventives in the field, indicate that they are most effective. These peculiar results, the failure of a neutral Bordeaux mixture to exert bactericidal action in vitro while in the field it has a considerable disease-preventive action, reopen the interesting

problem as to the theory of such action. It is hoped to advance further data that will narrow the scope of this problem.

The previous conclusions advanced concerning the action of formalin solutions against *Pseudomonas citri* in vitro are entirely corroborated by the results of the present experiments. The field evidence would even support a stronger conclusion than that advanced, since trees sprayed with formalin 1 to 100 actually showed a greater percentage of canker than those untreated. This directly controverts the unfortunate recommendation of Kellerman, (2) in the Yearbook of the United States Department of Agriculture, in which he suggests formalin 1 to 100 solution as a spray in citrus-canker eradication work. Not only would such a spray be a valueless expenditure of money, but field results indicate that the canker organisms may even have been disseminated by such a spray.

The favorable bactericidal results obtained with lime sulphur in vitro are also borne out in the present field tests. However, the lime-sulphur applications, since they are easily washed off by rains, do not show the same degree of preventive action as do the copper-precipitate sprays. Lime sulphur would be the preventive spray of unquestioned desirability, if means could be obtained for retaining it on the foliage.

COSTS OF THE CONTROL MEASURES

The foregoing conclusions being advanced, the question of the costs of these methods is immediately pertinent. The costs of the operations are shown in Tables 9, 10, and 11.

TABLE 9.—*Cost of labor in spraying operations; 288 trees.*

	Yen.
First application, June 3 and 6:	
Men: 56½ hours = 9 5/12 6-hour days, at Y 1.20 per day	11.30
Work animals: 13½ hours = 2 3/12 6-hour days, at Y 3 per day	6.75
Total	18.05
Cost per tree	0.075
Second application, June 24 and 25:	
Men: 84 hours = 14 6-hour days, at Y 1.20 per day	16.80
Work animals: 14 hours = 2⅓ 6-hour days, at Y 3 per day	7.00
Total	23.80
Cost per tree	0.10

TABLE 9.—*Cost of labor in spraying operations; 238 trees*—Continued.

	Yen.
Third application, August 24 and 25:	
Men: 66 hours = 11 6-hour days, at Y 1.20 per day	13.20
Work animals: 11 hours = 1⅚ 6-hour days, at Y 3 per day	5.50
Total	18.70
Cost per tree	0.06
Total cost for season	60.55
Total cost per tree for season	00.2544

The above figures include the time employed for the preparation of the spray mixtures, time lost because of unfavorable weather, and time required in repairing pump, harness, etc. The cost is representative of what would actually be the case in farm operations. Spraying in a commercial orchard, with but one mixture and without regard to plats of a limited number of trees, would undoubtedly result in lower labor costs.

TABLE 10.—*Cost of spray materials for the season.*

Plat No.	Spray used.	Quantity per plat.	Cost per plat.	Trees in plat.[a]	Cost per trees.	Remarks.
		Gals.	Yen.		Yen.	
1	No spray			22		
2	Lime sulphur 1-40	80	1.10	22	0.05	Trees smaller than average in orchard.
3	Bordeaux 4-4-50	80	1.54	22	0.07	Do.
4	Bordeaux neutral	65.5	1.12	22	0.051	Do.
5	Burgundy	82.5	1.57	22	0.071	
6	Lime sulphur	87.5	1.20	22	0.055	
7	Bordeaux 4-4-50	92.5	1.78	22	0.081	Rather large trees above average in orchard.
8	Bordeaux neutral	105	1.81	22	0.082	Do.
9	Burgundy	85	1.51	22	0.069	Do.
10	No treatment			22		Do.
11	Formalin 1-100	70	16.38	22	0.745	
12	No treatment			22		
13	Bordeaux neutral	29.5	0.52	10	0.052	
14	Burgundy	37.5	0.67	10	0.067	
15	Lime sulphur 1-40	37.5	0.52	10	0.052	
16	Bordeaux 4-4-50	42.5	0.82	10	0.082	
17	No spray			10		
18	No treatment			10		
19	Do.			10		

[a] A number of these trees were Unshiu (Satsuma) or Valencia orange trees. Although fruits from these plats did not enter into the experimental data, they were nevertheless sprayed in passing down the orchard rows; their number therefore is necessarily included in estimating the cost of the spraying operations.

TABLE 11.—*Total cost of control measures in each plat calculated per tree.*

Plat No.	Treatment.	Pruning (from Table 3).	Spray materials, 3 sprays.	Labor for spraying.	Total.
		Sen.	*Sen.*	*Sen.*	*Sen.*
1	Removal of sources of infection only	59.6			59.6
2	Infection sources removed; lime sulphur 1-40, 3 sprays	59.6	05.0	25.5	90.1
3	Infection sources removed; Bordeaux 4-4-50, 3 sprays	59.6	07.0	25.5	92.1
4	Infection sources removed; neutral Bordeaux, 3 sprays	59.6	05.1	25.5	90.2
5	Infection sources removed; Burgundy 3-3-50, 3 sprays	59.6	07.1	25.5	92.2
6	3 sprays, lime sulphur 1-40		05.5	25.5	31.0
7	3 sprays, Bordeaux 4-4-50		08.1	25.5	33.6
8	3 sprays, Bordeaux neutral		08.2	25.5	33.7
9	3 sprays, Burgundy 3-3-50		06.9	25.5	32.4
10	No treatment				
11	3 sprays, formalin 1-100		74.5	25.5	100.0
12	No treatment				
13	Pruning to remove infection sources; 3 sprays, Bordeaux neutral.	10.4	05.2	25.5	41.1
14	Pruning to remove infection sources; 3 sprays, Burgundy 3-3 50.	10.4	06.7	25.5	42.6
15	Pruning to remove infection sources; 3 sprays, lime sulphur 1-40.	10.4	05.2	25.5	41.1
16	Pruning to remove infection sources; 3 sprays, Bordeaux 4-4-50.	10.4	08.2	25.5	44.1
17	Pruning to remove infection sources; no other treatment	10.4			10.4
18	No treatment				
19	Do				

For the purpose of aiding those who wish to convert these costs into terms of American currency, the following comments are necessary:

The Japanese yen varies in value but is usually nearly equivalent to 50 cents United States currency; the sen is 0.5 cent United States currency. Japanese labor is not so efficient as American labor; it required five men to operate a hand-power spray pump with two lines of hose, which would be operated by three men in America. The Japanese laborers worked only six hours a day, whereas an American farm laborer would work at least eight, and more often nine or ten hours a day. A sled drawn by a cow was used as a conveyance for the spray pump; horses were not available. For the hire of the cow, 3 yen was paid for a six-hour day. This mode of conveyance was, moreover, extremely slow. The cost of spray materials in Japan is as high as, or probably in most cases higher than, the same supplies at most points in America. Those interested can, therefore,

compare for themselves the costs of spraying in Japan with those in America; the disadvantage to American conditions, if it exists at all, is very slight.

To summarize, then, a reduction from 80 to 96 per cent of cankered fruits on untreated plats, to 6.5 per cent on plat 3, cost 92.1 sen or 46 American cents per tree. This included very careful pruning of the trees. A reduction from 80 to 96 per cent to 34.5 per cent was obtained without pruning for 33.7 sen or, roughly, 17 American cents per tree. Formalin 1 to 100 solution, the least-effective spray, was incidentally by far the most expensive. The figures are presented in detail here and probably can be best interpreted for each country by those men in the industry closely acquainted with the markets. In America, however, with the highly developed competition for markets, this reduction of the blemish caused by canker would apparently be profitable at these costs. In oriental countries, where a blemish upon the fruit is not so important, possibly the expenditure for control would not be advantageous. These statements apply only to that class of citrus fruits having the susceptibility of the Washington navel.

It should be considered that there are factors which made these results less profitable than would be the case in ordinary years. First, the typhoons which occurred in early August are unusual in normal years. These typhoons were entirely unexpected, and the trees were entirely unprotected by preventive-spray coatings. One typhoon at this time would have been a considerable setback, but a second one is far from a normal seasonal occurrence. Another factor has been pointed out previously; namely, that continued spraying, year after year, would materially reduce the sources of infection, so that canker control should more nearly approach completeness with successive years. The results presented here, being those of the first year of control attempts, are not so favorable as they would be in a succeeding year.

RELATION OF WIND PREVENTION TO CANKER CONTROL

Another factor, that of protection against winds, could be improved upon in commercial work over that in the experiments. Although a row of a coniferous tree surrounded the orchard, such a windbreak was small and not sufficient to protect the whole orchard; a much more desirable condition could be provided. The data available to show the definite value of windbreaks follow:

A row of loquat trees ran across the experimental orchard from east to west. The situation of these loquat trees is shown

in fig. 1. These trees were not high, but afforded protection from the southwest typhoon winds to the citrus trees immediately adjacent to the north. The percentage of cankered fruits on these rows north of the windbreak is shown in Table 12.

TABLE 12.—*Showing the relation of windbreaks to the occurrence of citrus canker.*

Row, numbered from windbreak outward.	Total fruits.	Cankered fruits.	
		Number.	*Per cent.*
1	2,220	131	5.90
2	2,718	531	19.53
3	2,523	934	37.01
4	2,929	1,210	41.31
5	2,103	1,134	53.92
6	2,073	1,253	60.44
7	2,218	1,331	60.00
8	2,711	1,496	55.18
9	2,236	1,098	49.10
10	1,820	967	53.13

Row 1 was nearest to the windbreak, while the height of the windbreak, perhaps at most 6 meters, was not sufficient to protect the trees in rows 4 to 10. It is evident from this that much can be done to reduce canker infection by (*a*) location of the orchard to avoid such violent winds as may occur in seasonable periods favorable for canker development, and (*b*) the use of high, thick windbreaks. These conclusions have been corroborated repeatedly by field observations.

INFLUENCE OF COPPER SPRAYS UPON THE QUALITY OF THE FRUITS

Although canker was materially reduced by the copper sprays in these experiments, there were considerable disadvantages, evident at harvesting time, following the use of such sprays. These were an increase in red-spider infestation on sprayed trees, an increase of sooty mold, *Meliola cameliae*, upon the fruits, and an increase of melanose. The occurrence of these diseases upon the plats is shown in Table 13.

Table 13 shows very little sooty mold for unsprayed plats and for plats sprayed with lime sulphur and formalin. Plats sprayed with the copper mixtures show an increase to as high as 24 per cent of fruits affected with sooty mold; there is no evidence from this table that any one of the copper sprays is less serious in this respect than the others. The explanation generally accepted for such an increase of sooty mold following

fungicide applications is that fungi, parasitic upon injurious insects, are killed by the spray applications. The insects, when not limited by the parasitic fungi, increase enormously, and such species as secrete honey dew are then followed by sooty mold.

TABLE 13.—*Showing the results of the spray applications in increasing other diseases.*

Plat No.	Spray mixture employed.	Affected fruits.		Red-spider affection of fruits.
		Sooty mold.	Melanose.	
		Per cent.	*Per cent.*	
1	Canker removed by pruning; no spraying	0.75		None.
2	Canker removed by pruning; lime sulphur 1-40	1.37	4.04	Do.
3	Canker removed by pruning; Bordeaux mixture 4-4-50.	9.85	42.59	All fruits.
4	Canker removed by pruning; Bordeaux mixture neutral.	10.35	63.33	Do.
5	Canker removed by pruning; Burgundy mixture	4.20	61.03	Do.
6	No pruning; lime sulphur 1-40	0.59	0.59	Do.
7	No pruning; Bordeaux mixture 4-4-50	14.60	37.65	Do.
8	No pruning; Bordeaux mixture neutral	7.79	54.43	Do.
9	No pruning; Burgundy mixture	4.94	41.86	Do.
10	No pruning; no spraying; control	1.49	2.32	Very little.
11	No pruning; formalin 1-100	0.50		None.
12	No pruning; no spraying; control	0.20	0.40	Do.
13	Rough pruning; Bordeaux mixture neutral	2.58	61.15	All fruits.
14	Rough pruning; Burgundy mixture	2.85	53.26	Do.
15	Rough pruning; lime sulphur	0.82	2.15	Do.
16	Rough pruning; Bordeaux mixture 4-4-50	24.94	38.79	Do.
17	Rough pruning; no spraying; control	2.18	4.13	Very little.
18	No pruning; no spraying; control	1.14	1.36	None.
19	Do.	0.38	0.76	Do.

An unexpected development was the increase in blemish upon the fruits which was identical in appearance with the melanose injury due to *Phomopsis citri* Fawcett. The increase of a fungus disease with no insect relationships, following the application of fungicides, is notably peculiar. In this csae a greater percentage of fruits affected with melanose is quite definitely correlated with the neutral Bordeaux mixture applications. Burgundy mixture was somewhat less injurious, while Bordeaux 4–4–50 mixture was the least injurious of the copper sprays. Lime-sulphur and formalin applications resulted in little or none of this blemish. No attempt will be made to put forward an explanation for this; it is sufficient to call attention to this fact: that a blemish similar to melanose increased following applications of the copper-precipitate mixtures.

The third striking feature, very noticeable on the spray plats, was the increase of red spider following the applications of the

copper-precipitate mixtures. This increase of red spider was noticeably slight or absent from the lime-sulphur, formalin, and unsprayed plats.

The injury resulting from the red spider, melanose, and sooty-mold blemishes very largely depreciated the commercial value of the favorable results in the reduction of citrus-canker infections. However, the increase in sooty mold and red spider may be readily avoided by the addition of oil emulsions to the copper-precipitate sprays. In fact, it was through a misunderstanding between the writers that an insecticide was not added to the spray mixtures in August. It is suggested also that it might be desirable to spray with one of the copper sprays in June and July, and change to lime sulphur in August. A very noticeable result from the experiments, and one which elicited considerable favorable comment from the growers, was the luxuriant green of the foliage and the clear, flawless color of the fruits of the lime-sulphur plats. It would seem desirable, therefore, for future investigators to attempt a schedule of copper-precipitate sprays during the early part of the rainy period, changing to lime sulphur as the rains become less. Another suggestion for future experiments is that lime sulphur be employed at more frequent intervals. The control of sooty mold and red spider is so simple that these deleterious results scarcely need be considered as affecting the experimental value of the results showing canker reduction.

Following the use of the sprays employed in these experiments there was no noticeable insipidity or reduction of acidity of the fruits, such as has been described by Gray and Ryan (1) following lead arsenate sprays.

EFFECTS OF CITRUS CANKER UPON THE WASHINGTON NAVEL ORANGE

In the literature on citrus canker in America, very little has been stated as to the injuries resulting from the disease. This has been primarily because of the eradication work which has made continued observations upon commercial citrus plantings impossible. For a satisfactory understanding of the present control data it seems advisable to state briefly the effects of citrus canker in Nagasaki Prefecture, Japan.

Citrus canker affects the foliage and fruits of the Washington navel orange; twigs are rarely attacked and the mature wood is not commonly affected, as is the case with the very susceptible varieties of West Indian limes and American grape fruits.

Upon the foliage of the Washington navel, citrus canker must effect some reduction in the amount of leaf surface capable of functioning. An estimate of such injury is of course difficult but, to offer a comparison, it is somewhat similar to the effect of shot-hole disease of the apricot, or such similar leaf-spot diseases on the apple or the pear. Citrus canker, moreover, must shorten to some extent the life of an affected leaf, for such affected leaves are the first to drop on the occurrence of any slight stimulus, as a brisk shower or a strong spray application (see Plate 2, fig. 1).

The losses due to citrus canker upon the Washington navel, which would be most appreciated by the growers, are due to infections upon the fruits. A dropping of the fruits, infected while they were small, was observed upon the formalin plat and the untreated plats of these experiments. This is rather poorly shown in the photograph in Plate 2, fig. 2. This dropping of the fruits did not occur upon the treated plats lying adjacent, so that it is reasonable to assume that this fruit drop was due to the canker infections, and not to drought or other nutrition causes. The fruit drop due to canker was not sufficiently extensive to be appreciated by the commercial growers.

Secondly, the fruits if infected when larger, although they do not fall, are more or less blemished. In Japan this is not a serious handicap. In fact, infected fruits matured earlier than uninfected fruits, and the orchard coolies in selecting oranges for eating would choose those badly cankered, stating that they were sweeter.

In the United States, however, where marketing is considerably more advanced, the blemish due to canker would presumably necessitate lower prices for infected fruits. It is very difficult to state such losses except possibly by comparison. The blemish due to canker would be similar to peach scab or pear scab, but probably more abundant. Table 8 shows that blemished fruits due to citrus canker amounted to from 80 to 96 per cent upon untreated plats; this is of course a serious proportion. Such blemishes are shown in Plate 3, and an idea of the effect of these fruits in the market can be best obtained by those more familiar with market conditions.

Another loss, very difficult to appreciate, but fortunately apparent from the present experimental results, is due to a reduction in weight of fruits affected with canker. This is shown in Table 14.

This table shows an average loss in weight obtained from 40,523 fruits, of 0.2 gram per cankered fruit. This amount

is so small as to be considered negligible by many, yet in large orchards could amount to a tangible loss.

TABLE 14.—*Showing the weight of cankered fruits as compared with that of normal fruits.*

Plat No.	All fruits.			Canker-free fruits.			Cankered fruits.		
	Number.	Total weight.	Average weight.	Number.	Total weight.	Average weight.	Number.	Total weight.	Average weight.
		Kilos.	*Kilo.*		*Kilos.*	*Kilo.*		*Kilos.*	*Kilo.*
1	2,382	416.40	0.1742	1,313	232.40	0.1770	1,069	184.00	0.1720
2	2,692	471.35	0.1743	1,893	341.80	0.1805	799	129.55	0.1621
3	2,525	310.00	0.1227	2,292	274.70	0.1198	233	35.30	0.1515
4	1,169	189.40	0.1620	1,094	180.00	0.1645	75	9.40	0.1253
5	1,712	298.25	0.1742	1,395	247.10	0.1771	317	51.15	0.1613
6	2,668	457.20	0.1713	607	106.35	0.1752	2,061	350.85	0.1702
7	3,389	631.95	0.1864	2,130	403.85	0.1896	1,259	228.10	0.1811
8	2,963	514.15	0.1735	1,938	347.40	0.1792	1,025	166.75	0.1626
9	3,256	573.80	0.1762	1,739	322.90	0.1856	1,517	250.90	0.1653
10	4,601	796.50	0.1731	652	116.10	0.1780	3,949	680.40	0.1723
11	2,363	419.10	0.1773	91	12.30	0.1340	2,272	406.80	0.1789
12	2,487	441.15	0.1773	81	14.80	0.1827	2,406	426.35	0.1772
13	695	120.50	0.1773	489	86.05	0.1759	206	34.45	0.1672
14	1,224	212.40	0.1735	739	126.25	0.1708	485	86.15	0.1776
15	974	175.40	0.1800	504	91.90	0.1823	470	83.50	0.1776
16	1,299	228.90	0.1762	935	163.90	0.1752	364	65.00	0.1785
17	1,329	243.10	0.1829	453	87.30	0.1927	876	155.80	0.1778
18	2,271	404.10	0.1778	438	80.60	0.1840	1,833	323.50	0.1764
19	524	69.15	0.1319	38	4.85	0.1276	486	64.30	0.1323
Total	40,523	6,972.80	0.1720	18,821	3,240.55	0.1721	21,702	3,732.25	0.1719

Data concerning a possible loss in the number of fruits are available from Table 8; although varying orchard conditions affect these data, Table 8 shows no loss upon untreated plats as compared with treated plats. Nevertheless, the observations made in the early part of the spraying season, which recorded a fruit drop, indicate that there must be some loss in the number of fruits due to canker, although it is so small as not to be apparent at the end of the season.

Fruits affected with canker sometimes crack and split, but fruits whose surfaces are normal frequently do this also. However, cases have been seen where such splitting is very closely connected with the canker lesions. Two such cases are shown in Plate 4, fig. 1. Another injury due to canker, but seen very infrequently, is the infection with fruit-rot organisms, following citrus-canker lesions. Such cases are not at all common, however. Rot following a canker infection is shown in Plate 4, fig. 2.

These statements and figures of course apply only to the Washington navels, and varieties of similar susceptibility, such

as the oranges of Florida origin and some of the East Indian pummelos. The grapefruits and West Indian limes are affected much more seriously, both on the foliage and on the fruits. The Satsumas, Valencias, and mandarin oranges are not so severely affected.

To summarize, the injury to Washington navels caused by citrus canker is due to: (*a*) An indeterminable loss, due to a decrease in the functioning of infected leaves; (*b*) a scarcely appreciable loss, due to the dropping of fruits affected when young; (*c*) a loss in marketing, due to the blemish on affected fruits; (*d*) a slight loss in weight of cankered fruits; and (*e*) occasional secondary infection with fruit rots, following canker infection.

APPLICATION OF RESULTS

The reduction in amounts of canker recorded here on the Washington navel warrants the statement that a control for this disease is possible for hosts of this class of susceptibility and for less-susceptible species and varieties. Such a control appears to be feasible from a standpoint of costs. For commercial use it is recommended that Bordeaux 4–4–50 be used in periods of wet weather, while a change to lime sulphur should be made in periods of little rainfall. The utmost precaution is necessary to avoid increases in insects following copper sprays; for this reason an oil emulsion or other scalecide should be added to the Bordeaux mixture, probably with every application.

In the southern United States, where eradication work is still in progress, the use of preventive sprays, such as Bordeaux mixture with an oil emulsion, for trees adjacent to an infected tree will obviously reduce the chances for the spread of infection. In the past, formalin solutions have been frequently used; such solutions not only are more expensive but, at concentrations not injurious to the trees, also have no bactericidal or preventive value.

It also seems reasonable to suppose that lime-sulphur and Bordeaux-mixture applications, made for the prevention of citrus scab and other diseases, will greatly lessen the chances for canker infection.

The spraying schedule used for these experiments in Nagasaki Prefecture apparently requires slight changes. The application made on August 24 could be advanced to August 15, apparently with better results. Should the results warrant, two applications could be made during the typhoon period, in August and September. These statements of course apply only to Nagasaki

Prefecture. For other countries, in which canker is widespread, a spraying schedule should be worked out to agree with the climatic peculiarities of each region.

SUMMARY

1. Experimental work on the prevention of citrus canker upon trees of the Washington navel variety of the sweet orange, *Citrus sinensis*, is described.

2. The following results were obtained by these methods: Copper sprays without other treatment reduced the number of fruits affected with citrus canker to as low as 34, 37, and 46 per cent. Untreated plats had percentages of cankered fruits of 80, 86, 92, and 96 per cent. The cost of these spray applications for the season was from 32.4 to 33.7 Japanese sen per tree.

3. Lime sulphur without other treatment reduced canker, but not to such an extent as did the copper sprays. The applications of this spray for the season cost 31 Japanese sen per tree.

4. Formalin 1 to 100 solution did not reduce canker. On the contrary, the trees sprayed with formalin had a very slightly larger percentage of cankered fruits than did the controls. The cost of formalin sprays for the season was 1 Japanese yen per tree, or three times the cost of any of the other sprays.

5. Spraying with copper sprays, accompanied by a removal of the sources of infection before the period of canker activity, reduced the canker percentage on treated plats to 9.25 per cent, 6.5 per cent, and 18.5 per cent. The cost of such treatments was 92 sen for Bordeaux 4–4–50 mixture, 90 sen for neutral Bordeaux mixture, and 92 sen for Burgundy 3–3–50 mixture.

6. The trees treated for the removal of sources of infection, without other treatment, showed a reduction to 45 per cent of fruits cankered, at a cost per tree of 59.6 sen. Comments showing the comparative labor efficiency in Japan and America are made, which show that American orchard labor is but slightly more expensive than Japanese, if at all.

7. Data are presented to show that wind prevention in itself may reduce citrus-canker development from 50 to 60 per cent to 6, 20, and 37 per cent. This is also corroborated by numerous field observations.

8. Data were obtained from the spraying experiments which showed an increase to as high as 25 per cent of sooty mold, 63 per cent melanose, and 100 per cent red spider following the copper sprays. The percentages on untreated plats were less than 3 for sooty mold, and 5 for melanose, and there was no red

spider. There were slight increases in these troubles following the lime sulphur applications.

9. The injury of citrus canker to the Washington navel orange is described in detail, and consists of an indeterminable loss to the tree due to a slight reduction in functioning leaf surface, a slight loss due to dropping of fruits infected when young, the loss due to reduction in market value resulting from the blemish on fruits when cankered, a slight reduction in weight of affected fruits, and an infrequent secondary infection with fruit rots following canker infection. These statements do not apply to the more-susceptible limes and grapefruits nor to the less-susceptible Mediterranean sweet oranges, Satsuma oranges, lemons, mandarin oranges, calamondins, kumquats, or citrons.

10. It seems reasonable to conclude that, in countries where citrus canker is already widespread or universal, a feasible control may be obtained upon citrus fruits of the general susceptibility of the Washington navel. In regions such as Florida and the Gulf States of America, where an attempt is being made to eradicate the disease entirely, preventive sprays would materially lessen the chances for infection. Formalin 1 to 100, recommended by Kellerman for this use, is here shown to be entirely valueless as a preventive and, previously, as a bactericide; it is moreover three times as expensive as a copper spray. Lime sulphur, or Bordeaux mixtures with an oil emulsion, from these experiments, would seem to be the preventive sprays most effective for this use.

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ILLUSTRATIONS

PLATE 1

Showing the character of the experimental orchard at Saigomura, Nagasaki Prefecture, Japan.

PLATE 2

FIG. 1. Leaves affected with citrus canker fallen to the ground after a brisk shower.

2. Showing fruit drop of Washington navels due to canker. The cankers may be seen on some of the fallen fruits.

PLATE 3

FIG. 1. Fruits of Washington navel with citrus canker, showing injury to appearance.

2. Showing ill-looking scars on Washington navel fruits, due to citrus canker. The fruit to the left shows the skin beginning to crack.

PLATE 4

FIG. 1. Cracking of young Washington navel fruits, apparently connected with the canker lesions on the skin.

2. Secondary fruit rot on Washington navel following citrus-canker infection. This injury was very infrequent.

TEXT FIGURE

FIG. 1. Showing the arrangement of the experimental plats in the Washington navel orchard at Saigomura, Japan.

PLATE 1. CHARACTER OF THE EXPERIMENTAL ORCHARD AT SAIGOMURA, NAGASAKI PREFECTURE, JAPAN.

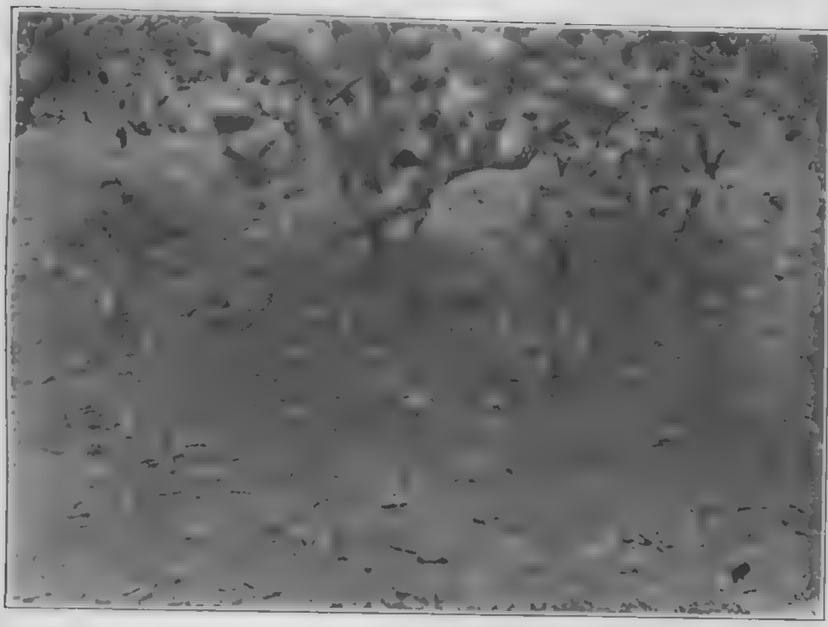

Fig. 1. Leaves affected with citrus canker fallen to the ground after a brisk shower.

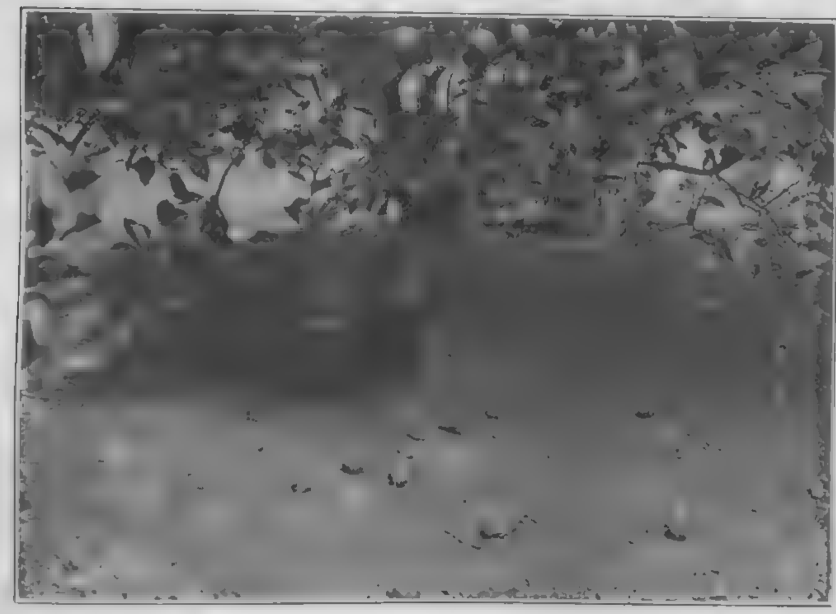

Fig 2. Showing fruit drop of Washington navels due to canker. The cankers may be seen on some of the fallen fruits.

PLATE 2.

Fig. 1. Fruits of Washington navel with citrus canker, showing injury to appearance. 2. Showing ill-looking scars on Washington navel fruits, due to citrus canker. The fruit to the left shows the skin beginning to crack.

PLATE 3.

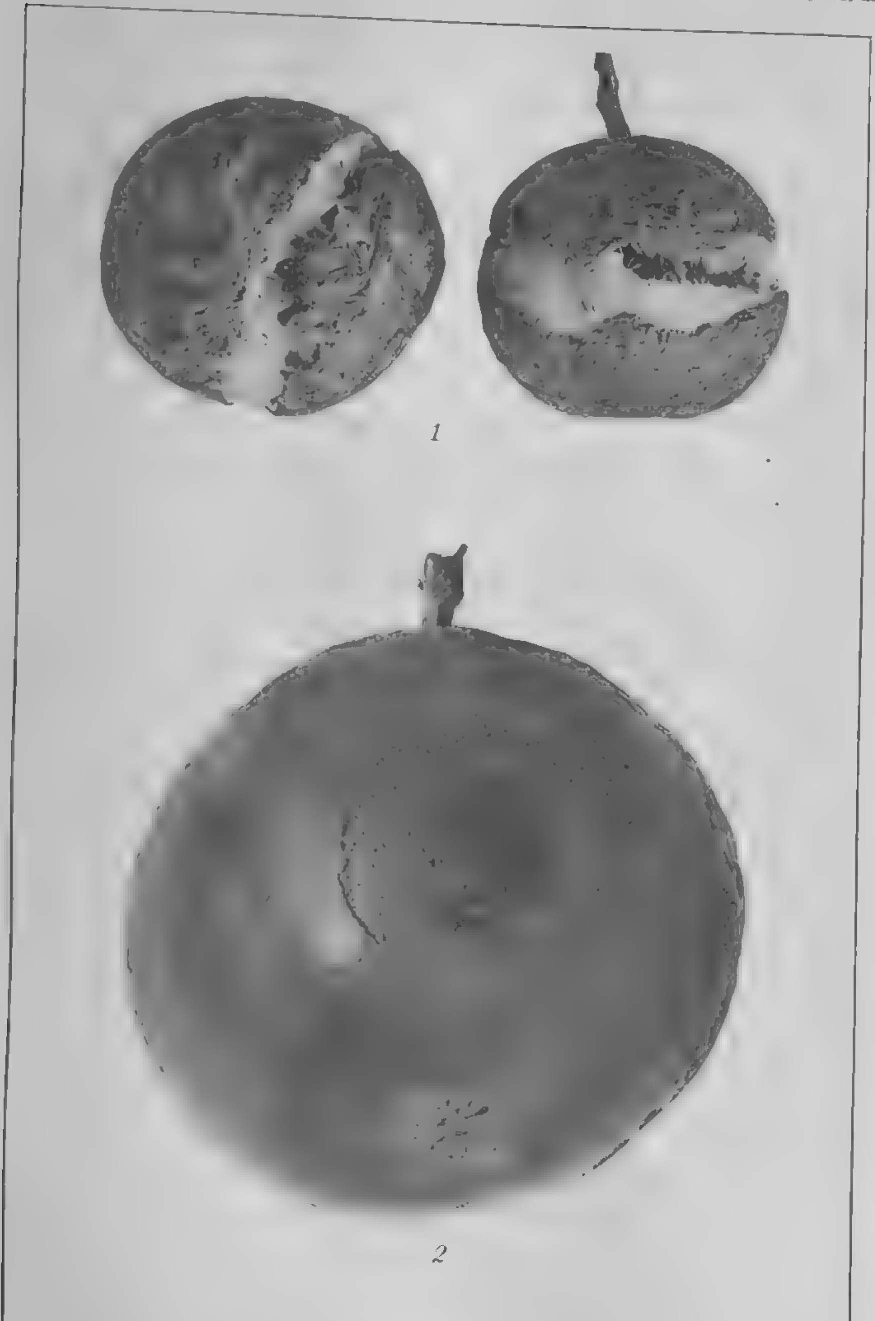

Fig. 1. Cracking of young Washington navel fruits, apparently connected with the canker lesions on the skin. 2. Secondary fruit rot on Washington navel following citrus-canker infection. This injury was very infrequent.

PLATE 4.

NEUE BRENTHIDEN VON DEN PHILIPPINEN UND BORNEO

Von R. KLEINE

Stettin, Germany

EINE TAFEL

Das von Herrn Prof. C. F. Baker gesammelte Käfermaterial der Philippinen und von Sandakan hat mir, soweit die Brenthidae in Frage kommen, durch die Liebenswürdigkeit Prof. Dr. Hellers zu Dresden vorgelegen. Sämtliche Typen sind im Dresdener Museum.

NEUE ARTEN VON DEN PHILIPPINEN

TRACHELIZINI

Cerobates costatus sp. nov.

Männchen.—Rotbraun, die postmediane Makel auf den Elytren undeutlich, Schenkel und Schienen an Basis und Spitze schwach verdunkelt.

Kopf hinter den Augen gerundet, Raum zwischen dem hinteren Augenrand und dem Hals etwa die Hälfte des Augendurchmessers. Oberseite platt, über den Hals vorgezogen, dreieckig eingekerbt, ungefurcht, zwischen den Augen eine elliptische Grube, überall einzeln, zart punktiert. Kopfseiten ohne Skulptur; Unterseite unter den Augen mit einzelnen Härchen.

Metarostrum ungefurcht, rundlich, Meso- und Prorostrum abgeplattet mit schwachem Mittelkiel. Metarostrum auf der Unterseite in einer grossen tiefen Grube endigend, Mesorostrum erweitert und in üblicher Weise einzeln grob punktiert.

Fühler bis über den Prothorax reichend, das erste Glied gross, walzig; das zweite kegelig, das kürzeste von allen; 3 bis 10 gleichlang, konischkegelig, vordere Glieder etwas schlanker, das elfte elliptisch etwas verlängert, alle Glieder zart und lang behaart.

Prothorax in der hinteren Hälfte deutlich gefurcht, vor dem Halse mit kleiner Grube, Punktierung einzeln, zerstreut, zart; Seiten und das Prosternum matt, ohne Skulptur.

Elytren mit durchgehenden Rippen und Furchen, alle Rippen bis auf den Aussenrand voll entwickelt, die zweite auf der Mitte verschmälert, die fünfte scharf gekielt; alle Rippen einzeln punktiert.

Metasternum und Abdominalsegmente 1 und 2 breit und flach gefurcht, zart punktiert, das vierte Segment schmäler als das dritte, das fünfte nur an der Basis glatt, sonst, namentlich am Hinterrand, dicht punktiert.

Länge, total, 5.5 millimeter; Breite, Thorax, 0.75 circa.

MINDANAO, Surigao.

In Sennas *Cerobates*-Tabelle[1] kommt man zu A. A., hh, Seite 215, wo *C. grouvellei* Senna und *birmanicus* Senna hingehören. Letztere Art scheidet von vornherein aus, es kann also nur *grouvellei*, die auch auf den Philippinen lebt, in Frage kommen. *C. costatus* wird durch folgende Merkmale getrennt: Kopf nach hinten über den Hals gezogen. Rostrum gänzlich ungefurcht. Metarostrum unterseits in einer grossen grubenartigen Aushöhlung endigend. Elytren mit vollentwickelten, starken Rippen versehen.

Die Verwandtschaft mit den obengenannten Arten ist aber sehr gross.

Miolispa persimilis sp. nov.

Männchen.—Kopf, Rüssel, und Prothorax grünlich erzfarben, Elytren schwärzlich braun, die dritte Rippe gelb, Unterseite rotbraun, Beine desgleichen, Schenkel und Schienen an Basis und Spitze und die Tarsen verdunkelt; am ganzen Körper hochglänzend.

Kopf mehr oder weniger gewölbt, ungefurcht, am Hinterrand tief dreieckig eingeschnitten, zwischen den Augen gefurcht, überall einzeln kräftig, zerstreut punktiert. Seitliche Einkerbungen des Hinterrandes viel kleiner als oberseits, Punktierung dichter als auf der Oberseite. Unterseite nur ganz zerstreut punktiert.

Metarostrum bedeutend kürzer als das Prorostrum, dreifurchig, Furchen etwa gleich breit, matt chagriniert, Mittelfurche als Fortsetzung der Kopffurche; Unterseite gerundet. Mesorostrum etwas erweitert, platt, Mittelfurche kaum verengt, Punktierung soweit vorhanden, kräftig; Unterseite flach gekielt. Prorostrum nach vorn allmählich breiter und platter werdend, Vorderrand rundlich, kurz eingebuchtet, Mittelfurche bis ein

[1] Notes Leyden Mus. 17 (1895) 209 ff.

Drittel der Länge kräftig, tief, Punktierung überall kräftig und ziemlich dicht; Unterseite am Mesorostrum gekielt.

Fühler robust, das erste Glied gross, das zweite ohne Stiel, breiter als lang, das dritte kegelig, länger als breit, 4 bis 8 breiter als lang, vom sechsten ab scharfkantig, das neunte und zehnte grösser aber breiter als lang, das elfte stumpf-konisch, basale Hälfte fast ohne Beborstung, dann zunehmend, 9 bis 11 dicht beborstet.

Prothorax eiförmig, am Halse stärker verengt als am Hinterrande, grösste Ausdehnung hinter der Mitte, Hinterrand schmal, scharf. Oberseite tief durchgehend gefurcht, rugos, einzeln punktiert. Nach dem Hals nimmt die Punktierung ab. Seiten zart punktiert, Unterseite fast ohne Skulptur.

Elytren an der Basis nach innen gebogen, Humerus spitz, Seiten parallel, nach dem Absturz verschmälert, hinten flach dreieckig eingeschnitten, Aussenecken stumpflich, rundlich, erste und zweite Rippe flach und breit, dritte breiter aber gewölbt, die folgenden schmal, konvex, erste, zweite, sechste, und achte bis auf den Absturz reichend, alle Rippen punktiert, die sechste mit drei starken, grossen, punktartigen Eindrücken, zwei an der Basis, eine auf der Mitte. Suturalfurche unpunktiert, die erste deutlich punktiert, von der zweiten an gitterfurchig.

Beine wie bei *M. novaeguineensis* Guér.

Metasternum nur an der Basis gefurcht, überall zart, zerstreut punktiert, an den Seiten etwas kräftiger, das erste und das zweite Abdominalsegment breit und tief gefurcht, Punktierung kräftig, Quernaht zwischen den Segmenten undeutlich, das dritte Segment etwas breiter als das vierte, an den Seiten und am Hinterrande dicht punktiert und zum Teil eng behaart.

Parameren mittellang, Lamellen fingerförmig, schwach aber lang behaart, Pigmentierung nur im vorderen Teil dunkler. Penis im Präputialteil schwach verengt, fast ganz hyalin, vorn zugespitzt, Pigmentierung dortselbst an den Seiten stark, braun.

Länge, total, 9.5 Millimeter; Breite, Thorax, 1.5.

MINDANAO, Kolambugan.

Die neue Art ist sehr nahe mit *M. novaeguineensis* verwandt und sicher auf den Philippinen Vicariante desselben. Unter allen Umständen trennen die Verschieden geformten Begattungsorgane sicher und einfach. Als äussere Erkennungsmerkmale sind zu nennen: Kopf am Halse nicht verjüngt, ohne Mittelfurche, Metarostrum nicht sammetartig und matt. Die sechste Rippe erreicht den Absturz und trägt drei Punkte statt nur einen. Metasternum schwach punktiert. Ferner besteht Aehnlichkeit

mit *M. mariae* Senna. Der Kopf ist dort auch gefurcht. Zwischen den Augen ist der Kopf dreifurchig, die seitlichen Einkerbungen sind grösser als die oberseitigen. Meta- und Prorostrum sind gleichlang. Die Fühlerglieder sind von anderer Form. Die Unterseite ist anders skulptiert.

Die drei Arten sind also hinreichend verschieden, sie stellen aber einen gemeinsamen Habitus dar, der aus dem asiatischen Gebiet bis Neu-Pommern zu verfolgen ist.

Hypomiolispa tomentosa sp. nov.

Weibchen.—Von gedrungener Gestalt, schmutzig ziegelrot, Spitze des Metarostrums, Halsring und Hinterrand des Prothorax, Sutura, eine postmediane Makel, der äusserste Seitenrand der Decken und die Beine in üblicher Weise schwarz.

Kopf (ohne Augen) länger als breit, Mittelfurche bis zur Augenmitte schmal, dann breit, dreieckig erweitert, Punktierung einzeln und grob, Oberseite und Seiten tomentiert, Unterseite neben den Augen punktiert, in den Punkten wie auch oberseits, behaart und tomentiert, eine flache Mittelfurche ist ohne Toment. Augen sehr gross, den ganzen seitlichen Kopf einnehmend, prominent. Der hintere Augenrand nicht gekerbt.

Metarostrum so breit wie der Kopf, gefurcht, Mesorostrum nur wenig erweitert und schmal gefurcht, die Furche bis auf das Prorostrum reichend. So weit sich die Furchung erstreckt, sind Kopf und Rüssel matt und tomentiert, Prorostrum glänzend.

Fühlerglieder 2 bis 8 quer, das neunte und zehnte mehr oder weniger kugelig, das elfte stumpfspitzig, alle Glieder locker gestellt und kräftig behaart.

Prothorax kräftig längsgefurcht und sehr grob rugos punktiert, nach dem Halse zu lässt die Punktierung nach, reicht seitlich aber bis zu den Hüften. Prosternum vor den Hüftringen mit einer Reihe grober Punkte. Elytren ohne besondere Merkmale.

Beine von normaler Gestalt, alle Schenkel an der Basis matt, sonst glänzend, unterseits mit einem sich über den ganzen Stiel bis zur Keule hinziehenden Toment.

Metasternum nur an der Basis, Abdomen nicht gefurcht. Rugose Punktierung des Metasternums stark und gross, auf dem ersten und zweiten Abdominalsegment schwächer, nach dem dritten zu ganz verschwindend, 3 bis 5 ohne Skulptur, hochglänzend, an den Seiten dicht filzig behaart.

Länge, total, 9.5 Millimeter; Breite, Thorax, 2.

MINDANAO, Iligan.

Die neue Art gehört in die erste Gruppe meiner Bestimmungstabelle[2] und ist durch den starken Toment auf Kopf, Rüssel, und den Schenkelunterkanten mit *H. exarata* Desbr. verwandt aber sehr leicht zu trennen, da die bei *exarata* an der Körperseite stark entwickelten Tomentstellen fehlen.

BELOPHERINI

Genus **YPSELOGONIA** novum

Weibchen.—Kopf fast quadratisch, nach den Augen etwas verengt, Hinterrand gerade, Hinterwinkel gerundet, Oberseite mässig gewölbt, Mittelfurche fehlend oder doch höchstens ganz obsolet, zwischen den Augen bestimmt flach gefurcht; Unterseite ohne Gularfurche, gewölbt, ohne Furche oder Kiel, warzig skulptiert. Augen mittlerer Stärke, hemisphärisch, in drei Viertel Augendurchmesser vom Hinterrand des Kopfes entfernt.

Metarostrum kürzer als der Kopf, rundlich, nach dem Mesorostrum zu verengt, Mittelfurche am Kopf breit angesetzt, nach vorn keilförmig verschmälert; Mesorostrum erweitert, schwach gewölbt, undeutlich schmal gefurcht, Unterseite mit einem starken, nach vorn-unten gerichteten, gekrümmten Zahn, der auf einer bis auf das Mesorostrum reichenden Leiste aufsitzt. Prorostrum drehrund.

Fühler sehr lang, fast von Körperlänge, das erste Glied lang, walzig, nach vorn verdickt, das zweite am kürzesten, kegelig, das dritte länger aber kürzer als die Folgenden, 4 bis 8 etwa gleichlang, schlank, vorn schwach verdickt, das neunte und zehnte nicht verlängert, das neunte höchstens von der Länge des achten, das zehnte bestimmt kürzer, das elfte am längsten, doch kaum so lang wie das neunte und zehnte zusammen, mehr oder weniger seitlich zusammengepresst. Alle Glieder ohne Stiel aneinandergefügt.

Prothorax elliptisch, drei Viertel so breit wie lang, grösste Breite in der Mitte, am Halse scharf ringförmig verengt, Hinterrand durch grubige Skulptur markiert, Oberseite mässig gewölbt, ohne Mittelfurche. Prosternum gewölbt.

Elytren an der Basis kaum in Thoraxbreite, flach ausgerandet, Humerus normal, Seiten nach dem Absturz wenig und allmählich verschmälert, Hinterrand flach dreieckig ausgeschnitten, hintere Aussenecken stumpflich zugespitzt. Sutura mit Ausnahme der Basis rechtwinklig, scharfkantig über die Decken

[2] Die Gattung *Hypomiolispa* Kleine, Ent. Bl. Berlin 14 (1918) 76.

herausragend, der übrige Teil der Decken scharf gitterfurchig, Furche breiter als die Rippen, Gitterung stark. Die zweite Rippe bis auf den Absturz gehend, die dritte und vierte daselbst vereinigt, stark, leistenartig erhöht und mit der neunten verbunden, 4 bis 8 alle von gleicher Länge, die fünfte, siebente, achte, und neunte höher gekielt als die übrigen, die fünfte an der Basis verbreitert, mit Schmuckstreifen.

Vorder- und Mittelhüften etwas getrennt, kugelig. Schenkel normal, keulig, ohne Zahn, Schienen schmal, gerade, Metatarsus aller Beine länger als das dritte Glied aber kürzer als das zweite und dritte zusammen, Sohlen filzig, Klauenglied normal.

Metasternum, das erste und das zweite Abdominalsegment kräftig gefurcht, Quernaht scharf, durchgehend, das dritte und vierte gleich gross, letzteres hinten gerade.

Typus der Gattung, *Ypselogonia peregrina* sp. nov.

Ypselogonia peregrina sp. nov.

Weibchen.—Kopf und Rüssel erdbraun, Fühler rotbraun, Prothorax ziegelrot mit dunkelbraunem Halsrand, Elytren rotbraun, die fünfte Rippe bis ins hintere Viertel schwefelgelb, Unterseite mehr oder weniger dunkelbraun. Beine hellbraun, Beine und Prosternum glänzend, sonst matt. Kopf und Metarostrum chagriniert, Prorostrum und die ganze Unterseite warzig skulptiert. Basale Fühlerglieder nackt, vom fünften ab mit schwacher Behaarung, vom siebenten mehr oder weniger grubig skulptiert. Prothorax fein chagriniert.

Schenkel fast ganz glatt, Schienen und Tarsen dicht und fein chagriniert. Körperunterseite von gleicher Skulptur.

Länge, total, 5.75 Millimeter; Breite, Thorax, 1.25 circa.

MINDANAO, Dapitan.

Die neue Gattung kann nur zu den Belopherini gebracht werden. Leider sah ich keinen Mann, um das Prorostrum festzulegen. Der Verlust ist aber nicht gross, da die von anderen Gattungen trennenden Merkmale so gross sind, dass keine Verwechselung möglich ist. Keine andere Gattung hat ungezähnte Schenkel, die Art der Rippenbildung ist noch nicht beobachtet, ferner ist die Lage des Schmuckstreifens auf 5 ganz unnormal. Auch die Fühler sind insofern eigentümlich, das sie kürzere End- als Mittelglieder haben. Im übrigen ist *peregrina* in Ausfärbung und Anlage der Schmuckzeichnung ein reines Philippinentier und neigt stark dem austromalayischen Typus zu.

NEUE ARTEN AUS SANDAKAN, BORNEO

Genus **HEMICORDUS** novum Amorphocephalidarum

Männchen.—Von Gestalt eines *Amorphocephalus.* Kopf länger als breit, vom Halse deutlich getrennt, am Hinterrand schwach nach innen geschwungen. Ueber den Augen liegt jederseits eine an *Cordus* erinnernde Leiste, die am vorderen Augenrand am schmälsten ist und sich nach hinten verbreitert und verflacht; die zwischen den Leisten liegende breite Furche daher am Hinterrand verschwommen. Vor den Augen schmale, aufrecht stehende Apophysen. Augen vorgequollen, oben und vorn gerundet, nach unten zugespitzt.

Metarostrum kürzer als der Kopf, dreieckig gegen das Mesorostrum erweitert. Die vom Kopf kommenden Leisten setzen sich scharfkantig auf den Rand fort und reichen fast bis zum Mesorostrum. Die Mittelfurche bleibt, neben derselben bildet sich vor dem Mesorostrum jederseits ein mässig erhabener Längskiel, der auf dem Mesorostrum verschwindet. Dieser Rüsselteil deutlich ausgebildet, über das Metarostrum erweitert, keulig verdickt, Mittelfurche wie auf dem Metarostrum, nach vorn erweitert. Prorostrum so lang wie das Metarostrum, nach vorn schmäler werdend, Seiten scharfkantig, vorn gerundet, das ganze Organ bildet eine von Kante zu Kante gehende Mulde, unter dem Vorderrand noch eine zungenartige Vorstülpung. Unterseite: Zwischen dem hinteren Augenrand und dem Hinterrand des Kopfes liegt eine tiefe Rinne, die sich unter den Augen entlang zieht. Die äussere Kante der Rinne verschmilzt mit den Apophysen, die innere setzt sich auf das Metarostrum fort und verschwindet am Mesorostrum, hier eine zapfenartige, glatte Fläche bildend, die von dicht chagrinierten Vertiefungen eingeschlossen wird. Mandibeln seitlich zusammengedrückt, vorn stark gezähnt.

Fühler von mittlerer Stärke, Basalglied lang, krugförmig, das zweite ohne Stiel, etwa quadratisch, das dritte kegelig, länger als breit, 4 bis 7 walzig, länger als breit (die folgenden fehlen). Alle Glieder stehen locker. Prothorax walzig-elliptisch, etwas gewölbt, ohne Mittelfurche, Hinterrand nur flach.

Elytren an der Basis breiter als der Prothorax, gegen den Absturz verengt, am Hinterrand flach, dreieckig ausgeschnitten. Alle Rippen entwickelt. Sutura breit, die folgenden Rippen

schmal, die zweite und dritte auf den Absturz gehend, die vierte im hinteren Drittel fehlend, fünfte und sechste etwas länger, die folgenden alle bis zum Rand reichend; Furchen breit und flach.

Vorder- und Mittelhüften eng stehend, fast zusammenstossend; Beine schlank.

Metasternum schmal, das erste und zweite Abdominalsegment breit gefurcht, das dritte grösser als das am Hinterrand schwach ausgerundete vierte, Apicalsegment gross, halbelliptisch, mit einer gleichgeformten flachen Vertiefung, die den grössten Teil des Segmentes einnimmt. Das dritte und vierte Segment gegen die Decken gezogen.

Es handelt sich hier um eine intermediäre Form, die zwischen *Cordus* und *Amorphocephalus* liegt. Da *Cordus* bisher auf Borneo nicht gefunden worden ist, sondern von Sumatra nach Australien und Neu-Guinea überspringt, so scheint es sich hier um eine vikariierende Gattung zu handeln. Auf Borneo findet sich eine durchaus gemischte Fauna der Amorphocephalini, hier scheinen die einzelnen Verwandtschaften an der Nordostgrenze zu liegen. Vielleicht ist *Cordus* früher ebenfalls bis hierher vorgedrungen, dann aber durch den *Amorphocephalus*-Typus verdrängt. Wichtig ist der Fund auf jeden Fall schon dadurch, als er eine Etappe der *Cordus*-artigen Formen bildet.

Typus der Gattung, *Hemicordus minax* sp. nov.

Hemicordus minax sp. nov.

Einfarbig violetbraun in verschiedenen Farbentiefen, Beine hellrotbraun, Schenkel und Schienen an Basis und Spitze und alle Tarsen am Vorderrand verdunkelt. Kopf und Rüssel nur ganz zerstreut und zart punktiert, Behaarung fehlt. Prothorax desgleichen. Elytren auf den Rippen mit weitläufigen Punkten. Unterseite des Körpers wie der Prothorax skulptiert und am Deckenrande einige grosse Punkte.

Länge, total, 9 Millimeter; Breite, Thorax, 1.25 circa.

BORNEO, Sandakan.

Die nach oben gezogenen Abdominalsegmente 4 und 5 weisen auf verwandschaftliche Nähe mit *Leptamorphocephalus* hin.

Leptamorphocephalus dissentaneus sp. nov.

Männchen.—Einfarbig tief violetbraun, fast schwarzbraun, am ganzen Körper hochglänzend.

Kopf am Hinterrand gerundet, deutlich vom Halse getrennt. Der Absturz gegen das Metarostrum beginnt erst auf der vorderen Hälfte, ist dreieckig von Gestalt, hat rundliche, unscharfe

Ränder und keine Behaarung. Skulptur aus äusserst feinen, zerstreuten Punkten bestehend, nur an der Kante zum Metarostrum dichter punktiert und einzeln zart behaart. Allgemeine Gestalt des Kopfes rundlich-walzig. Augen mittelgross, nicht über den seitlichen Kopf herausragend, flach; Unterseite gewölbt, ohne Skulptur, Gularnaht sehr klein.

Metarostrum an der Basis in üblicher Weise stark vertieft, seitlich durch die scheibenförmigen Apophysen begrenzt. Diese sowohl vom Kopf wie von dem übrigen Teil des Metarostrums völlig getrennt, dicht feinpunktiert aber unbehaart. Vorderer Teil des Metarostrums schildförmig, oberseits mehr oder weniger platt, mit schmaler, nach hinten erweiterter, abstürzender Mittelfurche, seitlich erweitert und in das mit dem Metarostrum verschmolzene Mesorostrum übergehend. Punktierung äusserst gering, Behaarung fehlt. Unterseite nach vorn keilförmig verschmälert, rundlich-walzig. Prorostrum verschmälert, nach vorn etwas an Breite zunehmend, aber immer schmäler als das Metarostrum. Die vom Letzteren kommende Mittelfurche erweitert sich, erreicht aber den Vorderrand nicht ganz; nach den Seiten steil abschüssig. Unterseite stark verbreitert, mehr oder weniger rechteckig. Mandibeln mittelgross, beide von gleicher Grösse.

Fühler robust, kurz, das erste Glied becherförmig, das zweite und dritte kegelig, das vierte etwa quadratisch, 5 bis 8 breiter als lang, walzig, das neunte und zehnte eckig-walzig, länger als breit, das elfte nicht so lang wie das neunte und zehnte zusammen. Vom fünften ab locker aneinander gefügt; alle Glieder stark grubig skulptiert.

Prothorax walzig-rundlich, ohne Mittelfurche, Skulptur aus zerstreuter, feiner Punktierung bestehend.

Elytren glatt, ausser der Skulptur ist keine Rippe vorhanden, nur an der Basis und am Absturz sind sehr geringe Reste davon sichtbar. Skulptur und Behaarung fehlt.

Beine ohne besondere Merkmale; das Klauenglied der Tarsen kurz, walzig.

Metasternum mit breiter, muldenförmiger Längsfurche. Das erste und zweite Abdominalsegment desgleichen. Naht zwischen den Segmenten nur an den Seiten erkennbar; Skulptur kaum vorhanden. Das dritte Segment grösser als das vierte, dasselbe ist gegen das fünfte nach innen ausgehöhlt. Apicalsegment sehr gross, fast ganz von einer flachen Depression eingenommen, die an der Basis des Segmentes kreisförmig von Gestalt ist. Skulptur nur am Hinterrande.

Länge, total, 7.5 Millimeter; Breite, Thorax, 1.25 circa.

BORNEO, Sandakan.

Eine Verwechselung mit anderen Gattungsverwandten ist nicht gut möglich. Die gänzliche Obliteration der Rippen ist bei keiner Art bisher beobachtet. Ebenso ist der kleine, rundliche Kopf noch nicht gesehen worden.

BEMERKUNGEN ZUR BRENTHIDENFAUNA DER PHILIPPINEN

NORD-LUZON OHNE NÄHERE BEZEICHNUNG DER FUNDSTELLE: LUZON

1. *Cyphagogus planifrons* Kirsch.
2. *Caenorychodes splendens* Kirsch.
3. *Henarrhenodes macgregori* Heller.
4. *Anepsiotes luzonicus* Calab.
5. *Hormocerus reticulatus* F.
6. *Heteroplites erythroderes* Boh.
7. *Diurus philippinicus* Senna.

SUMUAY, PROVINZ ILOCOS NORTE, LUZON

8. *Amphicordus improportionalis* Heller.

BAGUIO, PROVINZ BENGUET, LUZON

9. *Cyphagogus whitei* Westw.
10. *Miolispa pulchellea* Kleine.
11. *Schizotrachelus calabresii* Kleine.
12. *Schizotrachelus bakeri* Kleine.

IRISAN RIVER, PROVINZ BENGUET, LUZON

13. *Prophthalmus tricolor* Pow. forma *philippinensis* Kleine, ausserdem No. 3, 6.

IMUGAN, PROVINZ NUEVA VIZCAYA, LUZON

14. *Sebasius laetus* Senna.
15. *Jonthocerus bicolor* Heller.
16. *Miolispa robusta* Kleine.
17. *Miolispa clavicornis* Kleine.
18. *Hypomiolispa clavata* Kleine, ausserdem No. 3.

MOUNT LIMAY, PROVINZ BATAAN, LUZON

19. *Cerobates sexsulcatus* Motsch.
20. *Trachelizus bisulcatus* F., ausserdem No. 8, 12.

MOUNT MAQUILING, PROVINZ LAGUNA, LUZON

21. *Calodromus crinitus* Kleine.
22. *Calodromus mellyi* Guér.
23. *Sebasius pubens* Senna.
24. *Dictyotopterus philippinensis* Kleine.
25. *Stereodermus flavotibialis* Kleine.
26. *Cerobates tristriatus* F.
27. *Cerobates sumatranus* Senna.
28. *Miolispa pascoei* Kleine.
29. *Miolispa flavolineata* Kleine.
30. *Miolispa paucicostata* Kleine.
31. *Miolispa bicolor* Kleine.
32. *Hypomiolispa fausti* Senna.
33. *Baryrrhynchus (Eupsalomimus) schroederi* Kleine.
34. *Schizotrachelus corpulentus* Kleine.
35. *Diurus shelfordi* Senna, ausserdem No. 3, 9, 10, 12, 13, 19.

MOUNT BANAHAO, LUZON

36. *Cyphagogus gladiator* Kleine.
37. *Dictyotopterus pulcherrimus* Kleine.
38. *Jonthocerus pasteuri* Senna.
39. *Miolispa unicolor* Kleine.
40. *Miolispa siporana* Senna.
41. *Ectocemus badeni* Kirsch.
42. *Opisthenoplus fasciatus* Kleine, ausserdem No. 12, 13, 15, 16, 17, 19, 26, 27, 28, 29, 31, 34.

LOS BAÑOS, PROVINZ LAGUNA, LUZON

No. 12, 16, 19, 22.

MALINAO, PROVINZ TAYABAS, LUZON

43. *Miolispa fraudatrix* Kleine.
44. *Miolispa ephippium* Kleine.
45. *Miolispa strandi* Kleine.
46. *Hypomiolispa nupta* Senna.
47. *Schizotrachelus metallicus* Senna.
48. *Schizotrachelus brunneus* Kleine, ausserdem No. 19, 20, 25, 26, 27, 28, 35.

ALBAY, LUZON

49. *Miolispa pygmaea* Senna.

SURIGAO, MINDANAO

50. *Cerobates costatus* sp. nov.
51. *Hypomiolispa helleri* Kleine.
52. *Hypomiolispa exarata* Desbr., ausserdem No. 20, 41.

BUTUAN, MINDANAO

53. *Jonthocerus asiaticus* Kleine.
54. *Hypomiolispa tracelizoides* Senna.
55. *Heteroplites spinifer* Kleine, ausserdem No. 27, 28, 35, 46, 51.

ILIGAN, MINDANAO

56. *Cyphagogus longisetosus* Kleine.
57. *Jonthocerus laticostatis* Kleine.
58. *Cerobates adustus* Senna.
59. *Miolispa discors* Senna.
60. *Prophthalmus longirostris* Gyll.
61. *Caenorychodes serrirostris* Fabr.
62. *Apterorrhinus compressitarsis* Senna, ausserdem No. 8, 20, 27, 28, 29, 46, 47, 51, 52, 54, 55.

KOLAMBUGAN, MINDANAO

63. *Opisthenoxys ochraceus* Kleine.
64. *Higonius poweri* Lew.
65. *Miolispa persimilis* sp. nov.
66. *Diurus furcillatus* Gyll., ausserdem No. 3, 19, 20, 29, 33, 35, 57.

DAPITAN, MINDANAO

67. *Cerobates grouvellei* Senna.
68. *Ypselogonia peregrina* sp. nov.
69. *Achrionota bilineata* Pascoe.
70. *Schizotrachelus inconstans* Kleine, ausserdem No. 20.

DAVAO, MINDANAO

71. *Miolispa cruciata* Senna.
72. *Miolispa borneensis* Senna.
73. *Miolispa affinis* Kleine.
74. *Eupsalis* (*Schizoeupsalis*) *kleinei* Heller, ausserdem No. 5, 8, 12, 16, 19, 22, 34, 36, 51, 61, 70.

ZAMBOANGA, MINDANAO

75. *Miolispa elongata* Kleine, ausserdem No. 9, 12, 19, 24, 47, 52, 55, 63, 70.

AGUSAN, MINDANAO

No. 6

TAGOLOAN [a]

No. 5, 19, 20.

BASILAN

76. *Cediocera tristis* Senna, ausserdem No. 19, 29, 35, 36, 51, 52, 75.

PUERTO PRINCESA, PALAWAN

77. *Hoplopisthius trichimerus* Senna, ausserdem No. 19.

TAYTAY, PALAWAN

No. 6.

SÜD-PALAWAN, PALAWAN

No. 61.

Nach den Tribus verteilen sich Gattungen und Arten folgendermassen:

1. Calodromini. 5 Gattungen mit 11 Arten. Nur eine Gattung ist endemisch, neue Formen haben sich nicht ergeben.
2. Stereodermini. 3 Gattungen mit 11 Arten. Von ganz besonderem Interesse ist die Feststellung, dass *Stereodermus* in einer sicheren Art vorkommt. Der Verbreitungkreis dieser schon weit verbreiteten Gattung wird dadurch noch erweitert.
3. Trachelizini. 5 Gattungen mit 27 Arten. Auffällig ist die grosse Zahl an *Miolispa*-Arten (19), die sicher noch viel grösser ist. Neue Formen sind nicht gefunden worden.
4. Arrhenodini. 5 Gattungen mit 7 Arten. Am meisten interessiert die neue Gattung *Amphicordus*, die in ihrer gedrungenen, ganz abweichenden Gestalt kaum einer Arrhenodini ähnlich sieht und als ein entarteter Zweig des Verwandtschaftskreises anzusehen ist.

[a] Of José Algue, Atlas de Filipinas (1899) No. 27. On Baker's label, Tangcolan.

5. Belopherini. 4 Gattungen mit 4 Arten. Zwei Gattungen sind endemisch und neu.
6. Ceocephalini. 4 Gattungen mit 9 Arten, darunter keine neue Formen.
7. Ithystenini. 4 Gattungen mit 8 Arten; keine neue Formen.

Von den 30 Gattungen sind 4 Endemismen, von 77 Arten 38.

Ueber die Verwandtschaft zu den umliegenden Gebieten wäre folgendes zu sagen: Mit Borneo sind gemeinsam 3 Arten, mit Java 2 Arten, mit Sumatra 4 Arten, mit den Sundainseln allgemein 6 Arten, dabei sind einige, die von Ceylon bis Neu-Guinea überall verbreitet sind, nicht mit eingerechnet. Sechs Arten lassen sich bis Malakka verfolgen, einige sind bisher nur dort und auf den Philippinen gefunden, leben aber auch in den Zwischengebieten. Bis nach Ostindien ist eine Art verbreitet, bis Ceylon 4, 3 davon sind Ubiquisten. Bemerkenswert ist, dass die beiden aufgefundenen *Sebasius*-Arten auch in Birma leben.

Die mandschurische Fauna weist nur wenige Anklänge auf. Auf Formosa 2, davon eine nur dort und auf den Philippinen, Süd-China 1 Art (weitverbreitet).

Die Zahl der Arten aus den austromalayischen und australischen Gebieten ist klein. Mit Celebes fand ich 4 Arten gemeinsam, darunter zwei weitverbreitete und aus dem asiatischen Verbreitungsgebiet kommende. Im übrigen habe ich nur eine Art australischer Provenienz gesehen: *Baryrrhynchus* (*Eupsalomimus*) *schröderi*, die vom östlichen Neu-Guinea über die Molukken-Philippinen bis Tonkin zu verfolgen ist.

Nach den bisherigen Ergebnissen muss die Philippinenfauna als vorherrschend asiatisch angesehen werden, die Australier treten ganz in den Hintergrund. Dennoch ist eine Anlehnung an die Neu-Guineafauna ganz ohne Frage und zwar ohne Berührung der Molukken und von Celebes. Die für die Neu-Guineafauna charakteristische Doppelfärbung, roter Prothorax (eventuel auch Kopf und Rüssel) im Gegensatz zur dunklen Allgemeinfärbung, konnte ich an 10 Arten feststellen. Kein anderes Gebiet hat dieses Charakteristikum.

Von den 38 Endemismen kommen 29 auf Luzon, 9 auf Mindanao vor, Palawan hat keine mehr. Die doppelfarbigen Arten leben alle auf Luzon. Die Einwanderung asiatischer Elemente scheint also über Palawan stattgefunden zu haben, während auf Luzon auch austromalayische Einflüsse zu bemerken sind. Die Brenthidenfauna der Philippinen scheint demnach Mischcharakter zu haben.

TAFELERKLÄRUNG

Tafel 1

FIG. 1. Fühler und Deckenabsturz von *Ypselogonia.*

2. Kopf und Rüsselunterseite von *Cerobates costatus.*

3. Penis und Parameren von *Miolispa persimilis.*

4. Kopf und Fühler von *Leptamorphocephalus dissentaneus.*

5. Kopf von *Hemicordus.*

TAFEL 1. NEUE BRENTHIDEN.

FOLIAR TRANSPIRING POWER OF THE COCONUT[1]

By Sam F. Trelease

Of the Johns Hopkins University

ONE TEXT FIGURE

The purpose of this article is to describe the results of tests on the daily march of transpiring power of coconut (*Cocos nucifera* Linn.) leaves, as indicated by standardized cobalt-chloride paper. The method used was essentially the same as that described by Livingston (6) with, however, some of the modifications suggested by Trelease and Livingston, (14) and by Livingston and Shreve. (10) Small slips of filter paper impregnated with cobalt chloride were used; when dry the slips are bright blue, but upon absorbing moisture they gradually become pale blue, then pale lavender, and finally pink. The cobalt-chloride method of determining transpiring power involves a determination of the ratio obtained by dividing the time-period for a given color change over a standard evaporating surface (water-saturated porous clay covered with a millimeter of air) by the time-period for the corresponding change upon the leaf surface at the same temperature; the index of transpiring power thus obtained shows the relative power of the plant surface to give off water vapor, as compared with the corresponding power of the standard water surface. In the present tests the abundance of moisture in the atmosphere made it difficult to use the bright blue color as the initial shade (as recommended by Livingston and Shreve), and so the pale blue standard color used by the authors just mentioned was employed, the time being recorded for the change from the Livingston-Shreve pale blue standard to pink. The slips were standardized once for all in the laboratory, and each slip was given a coefficient, by which was obtained the time-period for the change over the standard evaporating surface at each time when leaf tests were made.[2] After standardization the slips were dried and then placed in small desiccators containing calcium chloride.

[1] Botanical contribution from the Johns Hopkins University, No. 72.

[2] See article by Livingston and Shreve (10) that is cited at the end of this paper.

A test upon a coconut leaf was made by holding a dried slip in contact with the lower surface of the leaf by means of a small glass clip, and noting the number of seconds required for the color change from pale blue to pink. The leaf was shaded during the test by means of a cheese-cloth screen, and the temperature of the air, which was assumed to be practically the same as that of the leaf, was recorded.[3]

As has been shown by several studies, the length of the time-period for a given color change over the standard evaporating surface depends, for any slip of paper, upon the temperature alone, this time-period being inversely proportional to the maximum vapor pressure of water corresponding to the given temperature.[4]

An example may illustrate the way in which calculations are made. In one of the tests, for a certain slip of cobalt paper the time-period for the color change on the leaf was 77 seconds when the air temperature was 23.7° C., corresponding to a vapor pressure of water of 21.76 millimeters. Since the slip of cobalt paper had required 31.9 seconds for the change over the standard surface when the temperature was 27.4° C., corresponding to a vapor pressure of 27.10 millimeters, the time-period required for the change over the standard surface at the temperature of the leaf would have been $31.9 \times 27.10 \div 21.76$, or 40 seconds. In this test the index of transpiring power, being the time required for the change over the standard surface divided by the time required for the change over the leaf at the same temperature, was 40 divided by 77, or 0.52. In making the calculations the table of vapor-pressure ratios given by Livingston and Shreve (10) was employed.

Tests were made upon coconut plants growing in the open field on April 29, April 30, May 3, May 4, May 7, May 8, May 9, May 10, and May 11, 1918. The experiments were conducted at the College of Agriculture, of the University of the Philippines, at Los Baños. The writer is indebted to Messrs. F. de Peralta and P. David for assistance in the experiments. Column 2 of Table 1 gives the average actual values derived from these tests, showing the indices of transpiring power for the various hours during the day and night. Since similar plants were used for all the tests and the environmental conditions did not vary

[3] See Edith B. Shreve. (13)

[4] See Bakke, (1) Livingston and Shreve, (10) and Trelease and Livingston. (14)

markedly from day to day, it seems reasonable to regard these averages as representing what may be expected to be the general course of the daily march of transpiring power for these plants at this season of the year.

TABLE 1.—*Fluctuation in the index of foliar transpiring power of Cocos nucifera, as indicated by standardized cobalt-chloride paper, and variation in apparent pinna width, together with evaporation data.*

[Relative values show percentage of range from lowest to highest values.]

Observation.			Index of transpiring power (lower surface).		Average apparent pinna width.		Evaporating power of the air (white spherical atmometer).	
No.	Time.		Actual.	Relative.	Actual.	Relative.	Actual.[a]	Relative.
	a. m.	*p. m.*			*mm.*			
1	6		0.56	100	33.4	78	----------	----------
2	7		0.52	87	----------	----------	0.8	28
3	8		0.52	87	32.6	58	1.3	45
4	9		0.53	90	----------	----------	1.9	66
5	10		0.52	87	31.3	25	2.3	79
6	11		0.49	77	----------	----------	2.7	93
7	12		0.46	67	30.3	0	2.8	97
8		1	0.45	63	----------	----------	2.9	100
9		2	0.44	60	30.9	15	2.8	97
10		3	0.42	53	----------	----------	2.7	93
11		4	0.39	43	31.2	23	2.4	83
12		5	0.40	47	----------	----------	1.9	66
13		6	0.38	40	32.2	48	0.6	21
14		7	0.36	33	----------	----------	0.5	17
15		8	0.35	30	32.8	63	0.3	10
16		10	0.27	3	34.3	100	0.1	3
17		12	0.27	3	34.3	100	0.0	0
18	2		0.26	0	34.3	100	0.0	0
19	3		0.33	23	----------	----------	----------	----------
20	4		0.36	33	34.2	98	0.0	0
21	5		0.52	87	----------	----------	0.1	3
22	6		0.54	93	33.8	88	0.4	14

[a] Cubic centimeters per hour for preceding hour.

As has been pointed out by Copeland,(5) there is a strand of colorless, thin-walled cells running along each side of the midrib on the undersurface of the coconut pinna, and these strands act as hinges. When the leaves are well supplied with water, the hinge cells are distended and the two pinna wings are held far apart; but when there is a progressive deficiency of water in the hinge cells, the wings of the pinna revolve downward, about the pinna midrib as an axis, so that their lower faces approach each other. The angle of divergence between the two pinna wings may be approximated by measuring the distance between

the two free, parallel edges. To study the daily fluctuations in "opening" and "closing" of the pinna, the distance between the two free edges of the pinna (called the "apparent width") was measured immediately after making each cobalt-chloride-paper test. The data thus obtained are given in column 4 of Table 1.

A Livingston white spherical atmometer, placed in full sunlight near the plants, was read at the times of measurement, in order to determine the evaporating power of the air, and the evaporation data are given in column 6 of Table 1.

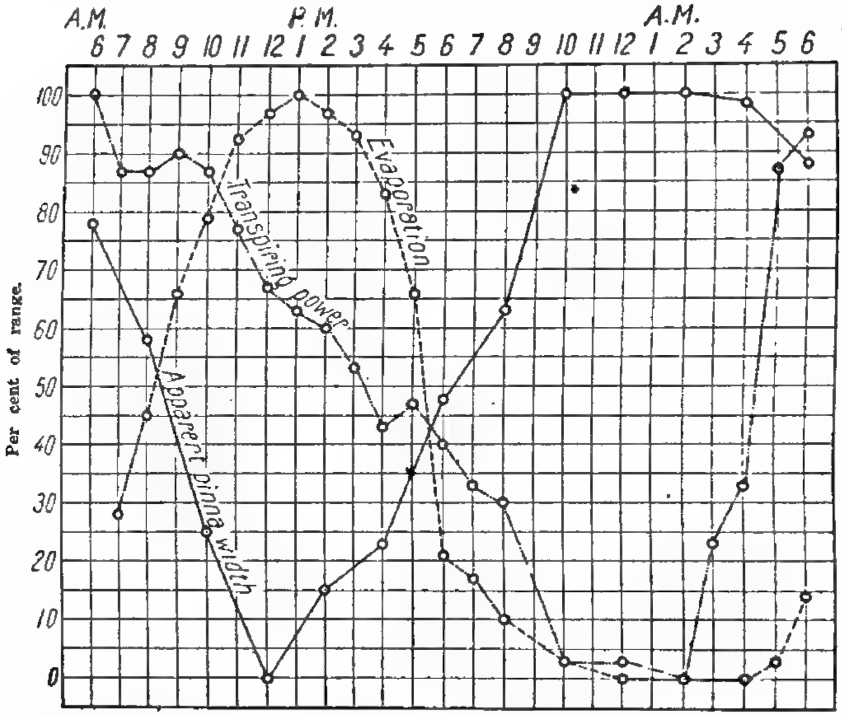

FIG. 1. Graphs showing transpiring power (dot and dash line) of *Cocos nucifera;* apparent pinna width (full line), and evaporating power of the air (dash line)—all plotted in percentage of range from lowest to highest values. (Data are from Table 1.)

To facilitate comparison between the changes in transpiring power, apparent pinna width, and evaporating power of the air, the actual values presented in the table have also been expressed as relative values, in terms of percentage of the total range in each case; and these relative values are shown for the three kinds of data in columns 3, 5, and 7, respectively. Transpiring power, for example, ranges in value from 0.26 to 0.56, the total range being 0.30. This range was divided into one hundred equal parts, and each actual value is expressed in the table as

a relative value in terms of the percentage of the range from the lowest to the highest actual value. These relative values, reduced to this uniform basis are presented graphically in fig. 1, in which the dot and dash line represents transpiring power; the full line, apparent pinna width; and the dash line, evaporating power of the air.

Inspection of the graph of foliar transpiring power (dot and dash line) shows that this has its maximum value at 6 a. m., a short time after sunrise. Approximately the maximum was maintained until 11 a. m. Then the index of transpiring power decreased rather gradually and uniformly until 8 p. m., and then decreased rapidly to a low night value. This low night index was maintained approximately constant until 2 a. m. From 2 to 4 a. m. there was a slight increase in the index of transpiring power, and from 4 to 6 a. m. there was a rapid increase to approximately the maximum value. The graph of the daily march of transpiring power of coconut thus resembles in a general way the published graphs showing transpiring power for other kinds of plants studied by the same method.[5] It is worthy of mention, however, that the maximum occurred earlier in the day for coconut than for other plants tested, and that the decrease in transpiring power therefore occurred earlier. Also, in coconut, although there was a fall in transpiring power during the time of approximately maximum evaporation rates, there was not the subsequent pronounced rise found by Bakke(3) for *Helianthus*.

Inspection of the graph (full line) that represents changes in the distance between the edges of the pinnae shows that this apparent width decreased uniformly from 6 a. m. until noon, and then increased uniformly until a maximum width was reached at 10 p. m.; this maximum was then maintained throughout the remaining hours of darkness. This graph illustrates the kind of change that is usually observed during the day in the apparent width of the pinnae. It is interesting to compare this graph with the graph (dash line) representing the hourly changes in the evaporating power of the air. Such a comparison shows that the changes in the evaporating power of the air exhibited a general inverse relationship to variations in the apparent width of the pinnae, since the evaporating power increased from 6 a. m. until noon and then decreased in the afternoon and reached a very low value after dark, the low value being maintained

[5] See Bakke, (1, 2, 3, 4) Livingston, (6) Shive and Martin, (12) and Trelease and Livingston. (14)

until nearly sunrise. After a period of rapid transpiration, due to high evaporation rates, Livingston and Brown(7) found that the water content of many kinds of leaves is markedly lower than it is after a period of slow transpiration (soil-moisture conditions remaining about the same), and that the diminished water content or incipient drying is in a general way proportional to the evaporation rates. Since apparent pinna width decreases with increased evaporation rates and increases with decreased evaporation rates, this inverse relationship may be taken as evidence of the truth of the assumption made by Copeland(5) that apparent pinna width may be used as an index of the water content of the hinge cells.

Returning to a consideration of the graph for transpiring power (dot and dash line), it will be of interest to discuss briefly, from our present knowledge of the water relations of plants, the influences that may be effective within the plant to bring about the increase in transpiring power to high values in the early morning, the decrease throughout the latter part of the day, and the decrease to low night values.

For many plant species foliar transpiring power has been found, in numerous investigations, to depend very largely upon the condition of the stomata—the stomatal aperture, or diffusive capacity, being by far the most powerful influence taking part in the control of foliar transpiring power of many plant species.[6] Thus the openness of the stomata frequently has such an important influence upon the daily march of transpiring power that other influences may safely be disregarded. It has long been known that the stomata of most kinds of plants respond to the stimulus of light by opening, and that in darkness they close; thus stomata are usually open during the day, and more or less completely closed at night.[7] But stomata also tend to close, as many observations have shown, when the water content of the leaf tissues becomes reduced as a result of high rates of transpiration accompanied by inadequate absorption, especially when the leaves have become noticeably wilted.[8] Besides the stomatal condition, another influence that may possibly have a pronounced effect upon transpiring power is the partial pressure of water vapor in the sub-stomatal spaces of the leaf; this should depend upon the state of the leaf tissues.[9]

[6] See Trelease and Livingston.(14)

[7] See Livingston and Estabrook.(8)

[8] See Lloyd.(11)

[9] See Livingston and Brown (7) and Trelease and Livingston.(14)

From the generally known facts briefly outlined above, the explanation may be advanced that the high transpiring power of coconut observed during the early hours of sunshine resulted from the fact that the stomata were wide open and that the leaf tissues were nearly saturated with water. The marked decrease beginning at about 11 a. m. was probably due to partial closure of the stomata and decreased partial pressure of water vapor in the leaf, both of these conditions probably depending upon a diminished water content of the leaf tissues. That such a diminution did occur is suggested by the observed decrease in the apparent pinna width. But it will be noted that the decrease in transpiring power continued during the afternoon, after the apparent pinna width had begun to increase—that is, after the water content of the hinge cells had apparently begun to increase. This may be taken to mean that the hinge cells respond more quickly (and with different critical values) to changes in water content than do the other leaf cells, which control transpiring power; apparently, although the water content of the hinge cells begins to increase in the early afternoon, the other leaf cells may still exhibit marked and increasing incipient drying, which may maintain a low partial pressure of water vapor in the sub-stomatal spaces of the leaf, or a reduced stomatal aperture, or both conditions together. The rest of the leaf tissues (or those controlling transpiring power) appear to go on drying out long after the hinge cells have passed their minimum of turgidity, and have begun to increase in size, thus lifting the pinna wings. The continued reduction in transpiring power in the very late afternoon may be regarded as due to stomatal closure in response to the reduced light intensity accompanying the setting of the sun; and the fall in transpiring power to the very low night values no doubt resulted from partial stomatal closure accompanying darkness. Such partial closure during the night is, of course, generally observed in plants having active stomata. The low values were maintained during the night until 3 a. m., and the very rapid increase in transpiring power from 4 to 6 a. m. was apparently due to the well-known rapid opening of the stomata during the period about sunrise.

The present tests were made upon only the lower surfaces of the leaves, because the stomata of coconut are limited to the lower surface; and preliminary tests showed that the transpiring power of the upper surface is extremely low, almost zero. Copeland(5) states that at least 98 per cent of the water trans-

pired by coconut is given off from the lower surfaces. Thus, considering both surfaces, the transpiring power would have values approximately half as great as those shown in Table 1; the maximum value would therefore be about 0.28, and the minimum, 0.13.

It should be emphasized that this paper deals with fluctuations in transpiring power, not in transpiration. Transpiring power represents only the group of internal conditions influencing the transpiration rate, which of course is also greatly influenced by environmental conditions. As numerous studies have shown, the actual amount of water transpired in a certain period of time from a given area of leaf depends upon two sets of conditions: (*a*) the transporting power of the leaf surface (controlled by the anatomical structure of the leaf, the number, distribution, and openness of the stomata, the way in which the leaf is exposed, the degree of saturation of the leaf with water, etc.), and (*b*) the effective external conditions surrounding the leaf (controlled principally by the evaporating power of the air—temperature of the air, moisture content of the air, movement of the air—and the intensity of the absorbed sunshine). Since, as is illustrated by the actual values in Table 1 and as has been shown by a number of investigations, the relative change in the most influential of the external conditions (the evaporating power of the air) is much greater from hour to hour or from night to day than is the relative change in transpiring power, it of course follows that changes in the actual rate of transpiration are determined very largely for a particular plant species by changes in the external conditions. Accordingly, for the whole night, as was found by Copeland,(5) the total transpiration from a coconut leaf may not be as much as one-tenth as great as for one hour of full sunshine. All studies thus far reported agree in showing that from night to day the transpiring power usually increases but slightly; in the present tests it increased in actual value from 0.26 to 0.56—that is, it became only about twice as great during the day as it was at night; the evaporating power of the air, however, in the day frequently becomes many times as great as it is at night. Numerous investigations with many kinds of plants have shown that the actual transpiration rate during the daylight hours may often be more than thirty times as great as during the hours of darkness. The transpiration rate is of course proportional to the product of the transpiring power of the plant and the evaporating power of the air, and the high rates of transpiration during the day

thus result from a small increase in transpiring power and a very great increase in the evaporating power of the air. For a further discussion of these features, the reader is referred to the literature; our present knowledge of the quantitative water relations of plants has been largely developed in the publications by Livingston.[10]

It should be mentioned, in connection with a consideration of the results of these tests, that the best-known methods for studying transpiring power may be expected to give somewhat different results when used on a plant such as coconut, in which the exposure of the leaf surfaces undergoes diurnal alterations. Only one of these methods (the one depending upon the power of the leaf surface to give off water vapor to a standard water-absorbing surface) was used in the present experiments. The other method, also devised by Livingston,[11] involves a comparison between absolute rates of transpiration and rates of water loss from some form of atmometer, the white spherical instrument being generally satisfactory; by this method the quotient of the transpiration rate divided by the evaporation rate from the standardized atmometer, for the same time-period and exposure, is used as a measure of transpiring power. It is not the purpose of this discussion to give a detailed comparison of these two methods, since only one of them was used in these tests; but one difference, which has not been emphasized in the literature, appears worthy of mention when coconut is considered. This dissimilarity is connected with the well-known fact that the position, or direction of exposure, of the leaf surface influences its transpiring power; thus it is generally recognized that a leaf, so placed that the rays of sunlight fall on it at right angles, is of course likely to transpire more rapidly than a similar leaf so placed that the rays strike it at a smaller angle; also, it has long been known that a leaf, freely exposed to the movements of the air, has a tendency to transpire more rapidly than a similar leaf that is protected from air currents. It is evident, as was pointed out by Copeland,(5) that the wings of the coconut pinna, when folding together in the middle of the day, alter their position in such a way as to tend to receive the sunlight obliquely and also to protect the lower, transpiring surface from air currents—the alteration in exposure thus tending to decrease transpiring power in these two ways. The two methods for measuring transpiring power may thus be expected to give

[10] For citations of literature, see Livingston and Hawkins.(9)
[11] See Livingston and Hawkins.(9)

somewhat different results, since the cobalt-paper method fails to detect differences in transpiring power due to changes in leaf position. It may be suggested, in conclusion, that the influence of such changes in leaf exposure as are here considered is a topic worthy of experimental investigation.

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ILLUSTRATION

TEXT FIGURE

FIG. 1. Graphs showing transpiring power (dot and dash line) of *Cocos nucifera;* apparent pinna width (full line), and evaporating power of the air (dash line), all plotted in percentage of range from lowest to highest values. (Data are from Table 1.)

THE CULTIVATION OF LEISHMANIA INFANTUM AND LEPTOMONAS CTENOCEPHALI ON THE TRIPLE-N MEDIUM [1]

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INTRODUCTION

The successful cultivation of trypanosomes on the artificial medium of Novy and MacNeal (3) has led in the past to its trial for *Leishmania*. The present inquiry was intended to find out what minimal amounts of blood could be used provided the proportion of agar be altered from that used in the original formula; and to what extent different degrees of softness of the whole medium would influence the growth of these protozoans.

MATERIAL AND PROCEDURE

Strains of *Leishmania infantum* and *Leptomonas ctenocephali*, which were furnished me through the kindness of Prof. E. E. Tyzzer, of the department of comparative pathology, Harvard Medical School, were used in these experiments. It was thought best to study these two organisms; because, while they have pronounced morphological similarities, they exhibit distinct biological manifestations, as *L. infantum* is the etiologic agent of a severe disease, infantile kala-azar, and the other is apparently a harmless parasite in the gut of the common dog flea.

Two culture media, one containing 2 per cent agar and the other 0.5 per cent agar, were used, to which different proportions of blood were added. The complete formulæ of the media are as follows:

Two per cent agar culture medium.

Agar-agar (grams)	20
Sodium chloride (grams)	4
Water (cc)	1,000

One-half per cent agar culture medium.

Agar-agar (grams)	5
Sodium chloride (grams)	4
Water (cc)	1,000

[1] Received July 1, 1921. From the laboratories of the College of Medicine and Surgery, University of the Philippines, and the Harvard School of Tropical Medicine.

These were heated in a flask until all of the agar was dissolved. One cubic centimeter of the mixture was placed in each of the small test tubes, which were autoclaved. The medium was then cooled to about 45° C.; different amounts of defibrinated rabbit's blood were then added and allowed to cool as slants. The organisms were streaked on the surface of the agar by means of a platinum loop.

This formula is essentially that of Nicolle,(2) which is a modification of Novy-McNeal's medium for trypanosomes. As modified by Nicolle, the medium consists only of agar, sodium chloride, water, and defibrinated rabbit's blood. The meat extract and peptone employed in the original formula are not used. This is best known as the triple-N or N. N. N. (Nicolle-Novy-McNeal) medium. Nicolle designed it for the cultivation of the organisms from a case of infantile splenic anæmia which he studied at Tunis. As the flagellates he recovered from the spleen showed similarity to *Leishmania donovani* he placed them in the same genus, but assigned to them a new specific name—*Leishmania infantum.*

It is worthy of note that Cristina and Cannata(1) also succeeded in growing *Leishmania infantum* by using media to which various other components were added, such as ascitic fluid, glycerine, bouillon, rabbit's serum, etc.

The results of the cultivation experiments are given in Tables 1 to 4.

TABLE 1.—*Leishmania infantum grown in 0.5 per cent agar plus different percentages of defibrinated rabbit's blood. Cultures inoculated December 1, 1920.*

5 per cent blood.	10 per cent blood.	25 per cent blood.	Date of examination.
Only one active organism was seen in several microscopic fields.	Negative	Negative	December 2, 1920.
Very scarce	do	do	December 3, 1920.
Numerous organisms	Good growth	Rather poorer growth.	December 6, 1920.
Many active organisms present (fewer than in 2 per cent agar-25 per cent blood examined on the same day.	Moderate growth; active ones also in water of condensation.	Slight growth	December 11, 1920.
Abundant growth	Moderate growth	do	December 17, 1920.
Good growth	Good growth	Poor growth	December 29, 1920.

INTERPRETATION OF RESULTS

The observations of the cultures from time to time as recorded in Tables 1 to 4 furnish indications with respect to certain re-

quirements for growth of these parasitic flagellates. Each of the two variables, namely, the amounts of agar-agar and of blood, as important constituents of the medium, has its own effect on their continued life.

TABLE 2.—*Leishmania infantum grown in 2 per cent agar plus different percentages of defibrinated rabbit's blood. Cultures inoculated December 1, 1920.*

5 per cent blood.	10 per cent blood.	25 per cent blood.	Date of examination.
Very few active organisms	Very few active organisms.	Very few active organisms.	December 2, 1920.
Do	do	Good growth	December 3, 1920.
Abundant growth	Abundant growth	Very abundant growth.	December 6, 1920.
Only trace of a few living organisms. Many dead individuals.	Good growth	Numerous active organisms; very good growth.	December 11, 1920.
Still a few living organisms	Numerous organisms.	Very numerous organisms. Isolated ones and also in clumps.	December 17, 1920.
Many dead organisms	Good growth	Very numerous	December 29, 1920.
Negative	Negative	Many granulated and degenerating forms. Some active.	February 6, 1921.

TABLE 3.—*Leptomonas ctenocephali grown in 0.5 per cent agar plus different percentages of defibrinated rabbit's blood. Cultures inoculated December 1, 1920.*

5 per cent blood.	10 per cent blood.	25 per cent blood.	Date of examination.
A few live organisms	A few live organisms.	A few live organisms.	December 2, 1920.
Good growth	Good growth	Good growth	December 3, 1920.
Very good growth	Very good growth	Very good growth	December 6, 1920.
Numerous	Numerous	Very numerous, many rosettes.	December 11, 1920.
Do	do	Very numerous	December 17, 1920.
Numerous; many dead organisms.	Numerous; many dead organisms.	do	December 29, 1920.

The addition of blood to the medium proved to be of distinct advantage and almost an essential in the hands of previous workers. However, it seems that consistency of the medium as a whole exerts no little influence. For instance, the writer got just as good results when using 0.5 per cent agar with 5 per cent blood as when he employed 2 per cent agar with 25 per cent

blood. Furthermore, better growth was obtained in 0.5 per cent agar with 5 per cent blood than in 2 per cent agar with 5 per cent blood, showing that the amounts of blood being equal, the resulting harder consistence of the latter due to a greater proportion of agar contained in it has given rise to lessened suitability of the medium for growth of the parasites.

TABLE 4.—*Leptomonas ctenocephali grown in 2 per cent agar plus different percentages of defibrinated rabbit's blood. Cultures inoculated December 1, 1920.*

5 per cent blood.	10 per cent blood.	25 per cent blood.	Date of examination.
Very few living organisms	Very few living organisms.	Very few living organisms.	December 2, 1920.
Some growth	Some growth	Fairly abundant	December 3, 1920.
Do	Fairly abundant	Numerous	December 6, 1920.
Numerous	Numerous	Very numerous	December 11, 1920.
Good growth	do	Very numerous, many rosettes.	December 17, 1920.
Good growth; not many dead organisms present.	Fairly good growth.	Very abundant	December 29, 1920.
Negative	Negative	Numerous active organisms.	February 19, 1921.

It was also evident in the cultures that *Leptomonas ctenocephali* seems to be less sensitive than *Leishmania infantum* as to changes in consistency of the medium, as no distinct deleterious effect was noticeable, particularly during the first days of the culture, by the use of varying amounts of either blood or agar. However, examination on February 19, 1921 (Table 4), something over two and a half months after the inoculation, showed that there was still growth in the 2 per cent agar and 25 per cent blood medium, while the other blood combinations of the 2 per cent agar yielded no growth at this time.

To summarize: Strains of *Leishmania infantum* and *Leptomonas ctenocephali* were used for cultivation experiments. Successful growth was obtained by using even a trace of blood provided the agar was very soft. The 2 per cent agar plus 25 per cent blood and the 0.5 per cent agar plus 5 per cent blood combinations seem to offer optimal conditions for growth.

I beg to acknowledge my gratitude to Professors E. E. Tyzzer and A. W. Sellards for the help they gave me while I was working in the laboratory of the Harvard School of Tropical Medicine.

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THE DIGESTIVE PROPERTIES OF PHILIPPINE PAPAIN[1]

By HARVEY C. BRILL and ROBERT E. BROWN

THREE TEXT FIGURES

Many methods have been proposed and their efficiency tested for measuring the proteolytic properties of papain and of other proteolytic enzymes. Some of these methods will be found in the references cited.[2]

D. S. Pratt[3] made use of a 40 per cent solution of sweetened, condensed, skimmed milk as his substrate and a 0.5 per cent water solution of papain as his enzyme solution. In his experiments these solutions were mixed and at the end of the digestion time the undigested casein was precipitated by the addition of 0.5 cubic centimeter of copper sulphate solution (60 grams per liter) followed by 0.5 cubic centimeter of glacial acetic acid accompanied by vigorous stirring during the precipitation. The precipitated casein was broken up, washed several times on the filter, dried in the oven, and weighed. By making use of a blank the percentage of casein digested was calculated. This method was thoroughly tried out, and reliable results were obtained in his investigation. Because of its simplicity and reliability we have adopted the same method in our work.

EXPERIMENTAL

Several samples of papain which had been used by Pratt in his work in 1914 were examined by us (seven years later) for proteolytic activity, and found to have lost all such activity. These samples represented papain that was extremely active

[1] Contribution from the chemical laboratory of Miami University, Oxford, Ohio.

[2] Delauny and Bailly, Bull. Sci. Pharm. 20 (1913) 241; Van Dam, W., Z. physiol Chem. 79 (1913) 247; Mendel, L. B., and Blood, A. F., Journ. Biol. Chem. 8 (1910) 177; Long, J. H., and Barton, A. W., Journ. Am. Chem. Soc. 36 (1914) 2151; Sherman, H. C., and Neun, D. E., ibid. 38 (1916) 2199; Falk, Chemistry of Enzymes, Chem. Cat. Co. (1921); etc.

[3] Philip. Journ. Sci. § A 10 (1915) 1.

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[3] Philip. Journ. Sci. § A **10** (1915) 1.

and digested 85 per cent of the casein of milk in thirty minutes when examined by Pratt in 1914. The dry material had been sealed up in small sample vials of glass and had lain in a pigeon-

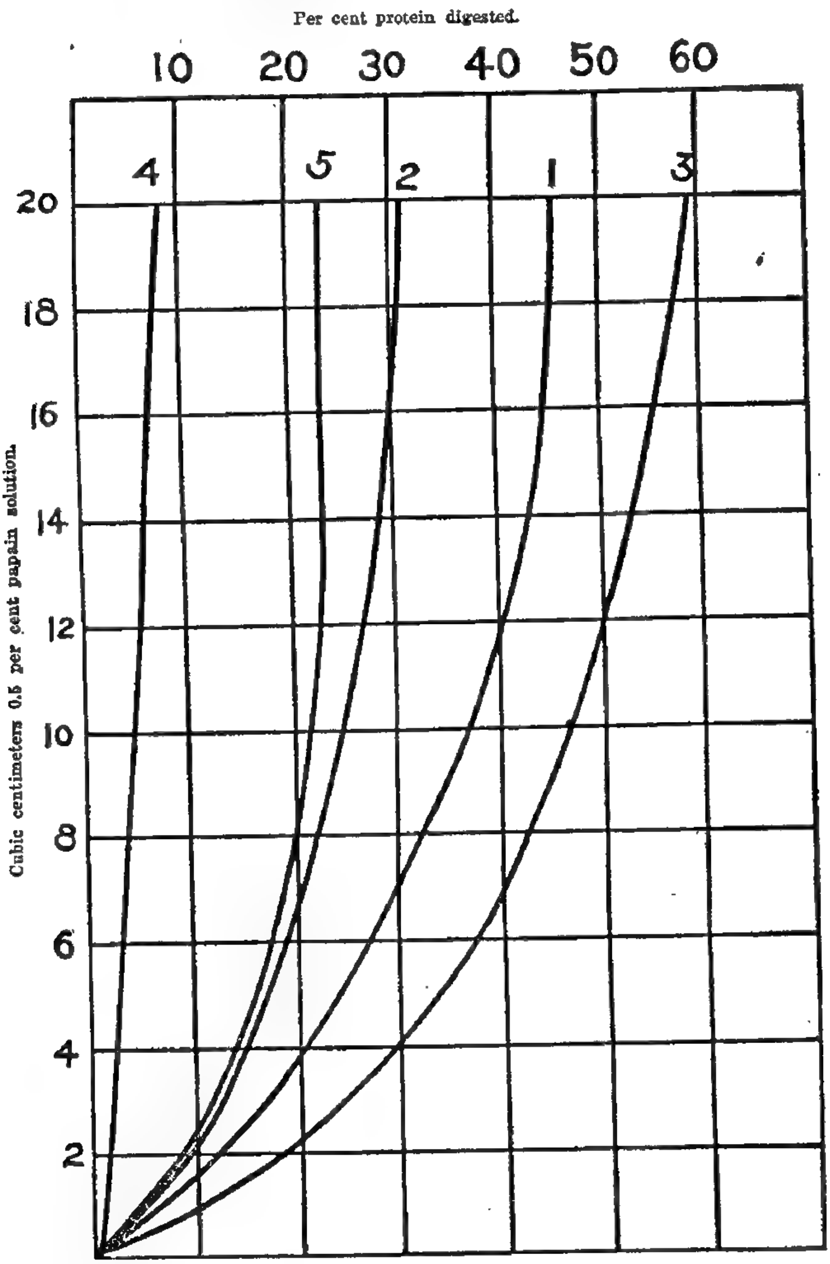

FIG. 1. Curves showing results of experiments with papain solution.

hole in the desk, protected from the sunlight most of the time since. Apparently papain may lose its activity with age, and this probably accounts for much of the inferior papain found in the market.

The papain used by us was furnished by the Bureau of Science, Manila, Philippine Islands.[4] The only deviation from Pratt's procedure introduced by us was the use of a 10 per cent solution of skimmed-milk powder as the substrate instead of the sweetened, condensed, skimmed milk. The milk powder is more readily handled and remains sweet for an indefinite period when open to the air. It was, therefore, substituted for the sweetened, condensed, skimmed milk which had been used by Pratt. Curve 1 is for sundried papain; curve 2, for alcohol-precipitated papain; curve 3, for alcohol-precipitated papain with milk that had been dialyzed at 20° C. for fourteen hours; curve 4, for alcohol-precipitated papain that had been dialyzed at 20° C. for fourteen hours; curve 5, for papain solution that stood at a temperature of 0° to 5° C. for seventeen hours.

Our results are in accord with those of Pratt, who found the alcohol-precipitated enzyme to be more active than the sundried material. Curve 4 was determined in the hope that a separation of the papain from any co-enzyme might be made by dialysis and the co-enzyme identified, and curve 3, that the mineral salts present in milk might be removed. Curve 3 shows greater activity than does any other curve in fig. 1. Curve 4 shows much less activity than curve 1. To determine whether the lessened activity was due to the removal of a co-enzyme or to a partial autolysis of the enzyme, the experiment shown by curve 5 and another (the curve for which is not included) were carried out. Curve 5 shows lessened activity of the enzyme, which indicates that the enzyme decomposes at a temperature as low as 0° to 5° C. in the presence of water. The unrecorded curve showed a maximum digestion of 10 per cent when a 0.5 per cent solution of papain is allowed to stand sixteen hours at a temperature of 15° C. This proves that the decrease in activity for curve 4 is due to the decomposition of the enzyme, probably by autolysis, and not by the removal of a co-enzyme.

[4] Mr. A. H. Wells, chief of the division of organic chemistry of the Bureau of Science, kindly furnished us with two samples, one sundried and the other alcohol precipitated. The latter was practically white. The alcohol-precipitated sample showed the greater digestive powers.

The curves in fig. 2 are the results from further attempts to dialyze papain solution: Curve 6, at a temperature of 16° to 19° C. for four hours; curve 7, at about freezing for sixteen hours; and curve 8, at a like temperature for twenty-four hours. Even for so short a time as four hours a great decrease in activity takes place at 16° to 19° C. Dialysis at temperatures near freezing was not successful, since decomposition of the enzyme took place, as is indicated by curve 5, fig. 1.

All the curves in fig. 3 are the results of using 10 cubic centimeters of 0.5 per cent papain solution with 25 cubic centimeters of 10 per cent solutions of skimmed-milk powder with varying quantities of salts or acids (see Table 1). The total volume of the mixture was equal to 50 cubic centimeters.

In as much as the literature relative to the influence of acids and bases on the digestive activity of papain is contradictory, it was thought to be worth while to investigate their influence and that of several salts.

The results of the latter investigation are set forth in fig. 3 and in Table 1.

TABLE 1.—*Influence of various compounds upon the activity of papain.*

Curve No.	Salt or acid solution.	Strength of salt or acid solution.	Concentration of salt or acid at point of maximum effect.		Casein digested at point of maximum effect.
		Per cent.	*Per cent.*	*Effect.*	*Per cent.*
6	NaCl	10	0.90	Activates	22
			[a] 2.00	Inhibits	9
7	Na_2CO_3	8		Inhibits at once	26
8	$NaHCO_3$	4		do	8.5
9	$CaCl_2$ [b]	8		do	29
10	$MgSO_4$	4	0.32	Activates slightly	41
			[a] 0.80	Inhibits slightly	38
11	H_3BO_3	2	0.32	Slightly inhibits at once	30
12	KCl	4	0.32	Activates	45
13	Na citrate	5	0.60	do	52
14	CH_3COOH	2.5	[a] 0.50	Inhibits at once	6
15	$CH_3CHOH\ COOH$	5	[a] 1.00	do	18

[a] Maximum concentration used.
[b] $CaCl_2$ substituted for $CuSO_4$ in the precipitation of the milk protein.

CONCLUSION

Autolysis of papain takes place at temperatures as low as 0° C. when the enzyme is put in water solution with toluene as an antiseptic. Air-dried samples in sealed glass containers

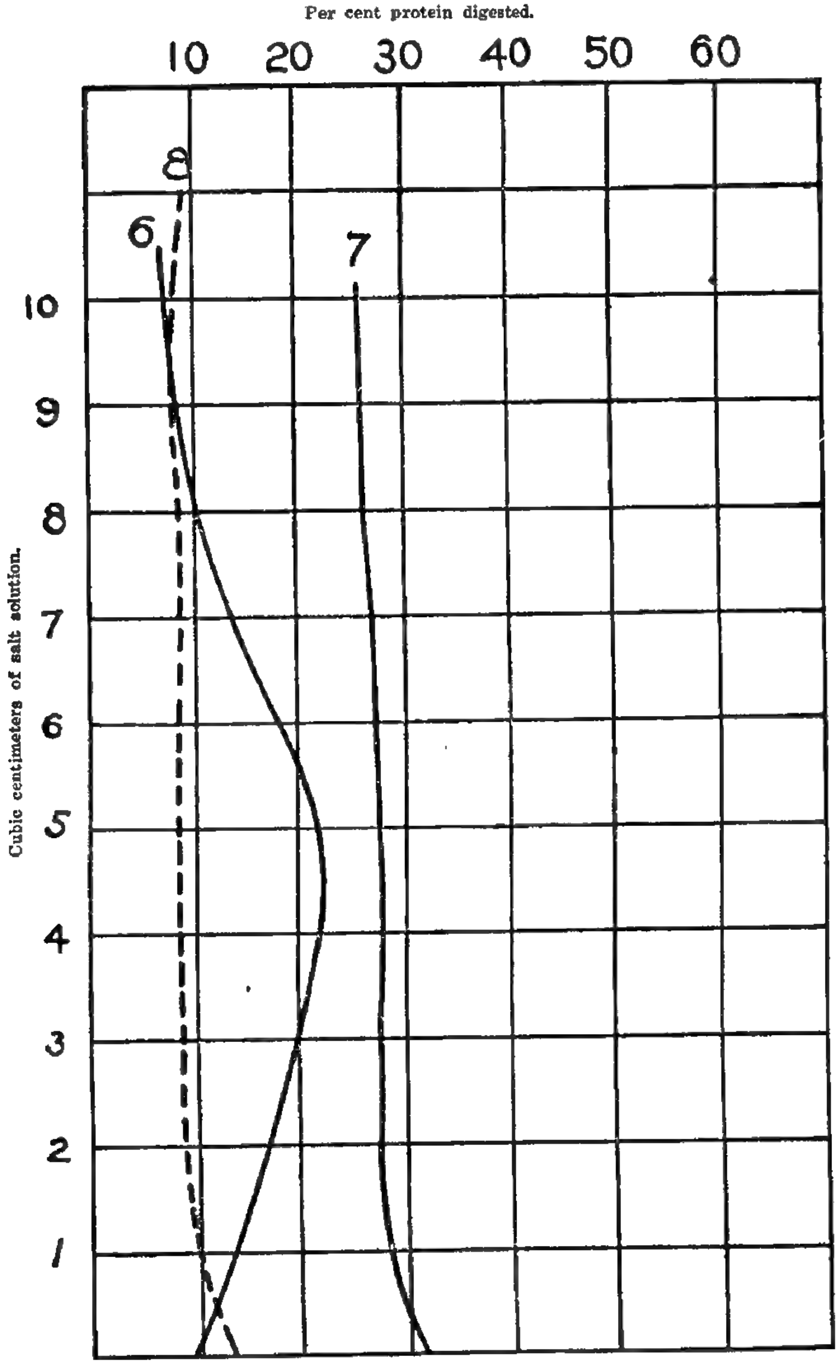

FIG. 2. Curves showing results of experiments with salt solution.

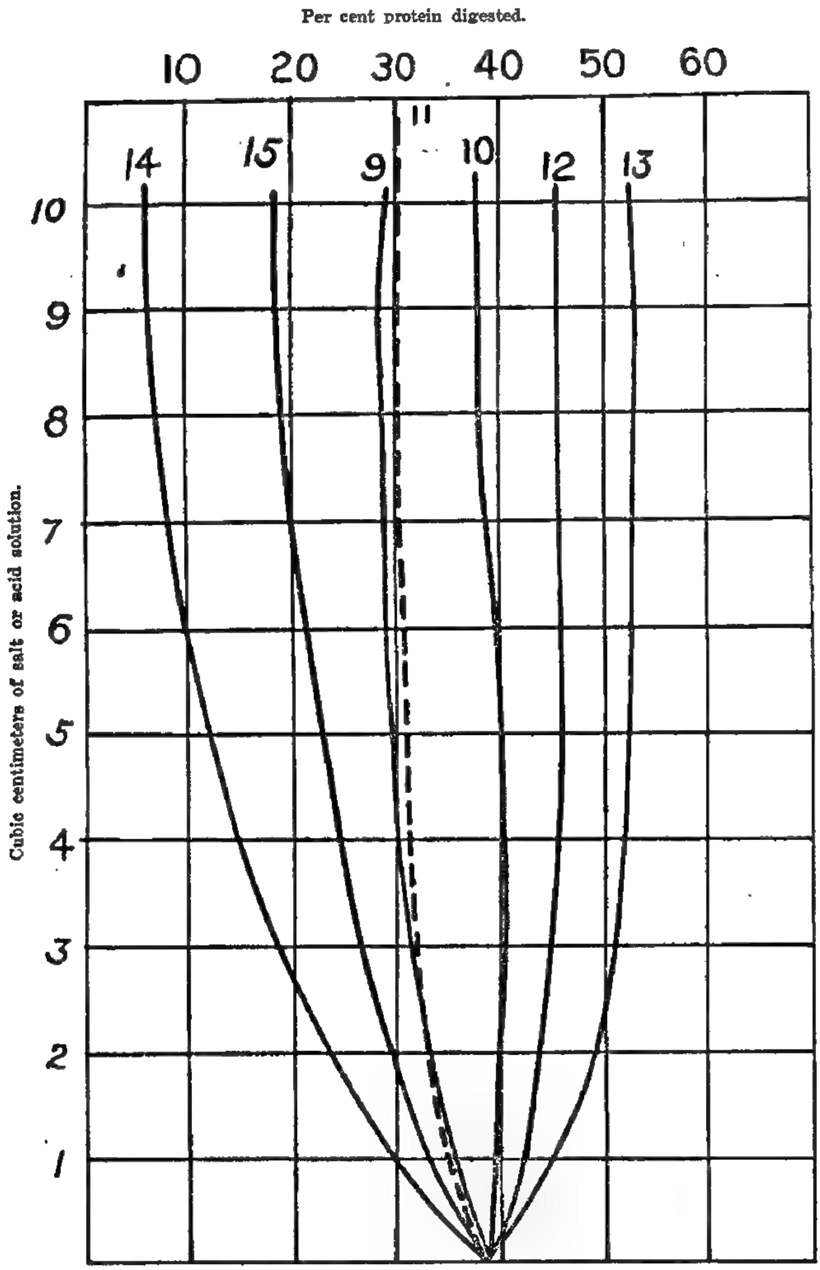

FIG. 8. Curves showing results of experiments with salt or acid solution.

had lost their activity at the end of seven years. Sodium chloride shows first a slightly activating effect, followed by an inhibiting effect in more-concentrated solutions. Sodium carbonate, sodium bicarbonate, calcium chloride, magnesium sulphate, and boric acid have no marked influence; potassium chloride and sodium citrate showed marked activating influence; while acetic acid and lactic acid, contrary to the findings of Vines[5], and of Mendel and Blood[6] with hydrocyanic, a weak organic acid, showed strong inhibiting effects.

[5] Am. Bot. 17 (1902) 606.
[6] Journ. Biol. Chem. 8 (1910) 182.

ILLUSTRATIONS

TEXT FIGURES

REVIEW OF PHILIPPINE PALEONTOLOGY

By Roy E. Dickerson

Honorary Curator, Department of Paleontology, California Academy of Sciences, San Francisco

SIXTEEN PLATES

INTRODUCTION

The study of ancient life in the Philippines has great economic value in connection with the stratigraphy of sedimentary beds containing coal and oil and with the associated strata. The relative geological age of rocks in a given district may be determined by a study of the order of deposition, if there have been no great disturbances such as faulting and intense folding; but such an ideal condition is seldom obtained. In the Philippines, in addition to the above-mentioned factors, a heavy cover of forest and high grass obscures the rocks, and the land masses are broken by deep seas. Partially to reassemble the shattered mosaic of the past, one must study the "Books of Rock" and their fossil contents. In this way only can the geological history be read and the patterns of Nature be deciphered. At best, the evidence will be incomplete but often after much labor a fairly complete outline of the design can be obtained.

For the benefit of the layman, it is necessary to state a few of the principles of paleontology, the study of ancient life. That the life of the present was evolved from the past is axiomatic in this study. Life through long geological ages has been continuous, and on this account such a discontinuous record as is evidenced in the succession of different rocks in a given area can only be interpreted by reference to this unbroken life line and to the fossil record in far distant regions. On account of this fossil record paleontological advances depend upon world-wide investigations by many workers, and a certain familiarity with this great world field is necessary for arriving at broad conclusions. Such extensive studies indicate that, once a species is extinct, this particular life form is never again repeated. This principle is particularly useful in picking out special fossils which indicate certain beds. These horizon determiners are

almost invariably extinct forms, and the determination of the geological time during which they lived can only be made after much collection in many localities. In general, these extinct forms are the highly organized ones which have developed special adaptations particularly suited for their immediate environment. A slight change in climate, food, or salinity may be sufficient to cause such forms to become extinct or to develop other habits. New habits quickly, geologically speaking, may cause specific changes and a new species may result. The recognition of such evolutionary series of forms makes it possible for the paleontologist to recognize comparatively small divisions of geological time, and its importance in oil and coal work is very great. In temperate latitudes these changes are marked; but recent work by the writer indicates that in the Tropics, where climatic changes have been but slight, evolution has proceeded much more slowly. As was stated above, the highly organized species make the best horizon determiners, and one fossil like *Vicarya callosa* Jenkins is of more value in horizon determination than several dozen others associated with this extinct but once widespread Asian species. Corals are highly specialized, and on this account they should prove particularly useful in the Philippines.

ECONOMIC USES OF PALEONTOLOGY

A few examples of the economic uses of paleontology will suffice to indicate that this study is important in practical explorations for certain highly useful substances. In California an oil company was starting a well on a supposed anticline (upfold). Sandstone on the west flank looked like the sandstone on the east, and the operators located approximately between the two flanks. A paleontologist examined the property, and he collected upper Cretaceous fossils from the west side and Miocene fossils from the east side, thus demonstrating that the oil operators were drilling not on the anticlinal axis but upon a great fault, an ancient break in the earth's crust, a very unlikely place for accumulation of oil. Long ago the Cretaceous strata had been moved upward hundreds of feet and the Miocene downward, faulting out all of the Eocene and Oligocene. This half hour's work by the paleontologist caused the operators to save thousands of dollars, as failure was certain in this spot.

For many years much time and money were spent in New York in search of coal, as the neighboring state, Pennsylvania, had an abundance. Hall, state geologist of New York, showed that the Paleozoic formations of New York were far older than

those of Pennsylvania and were deposited in deeper marine waters and not in the quiet waters of a low-lying coastal plain that characterized the conditions of deposition of the coal formations of Pennsylvania. This definite conclusion was reached only by a careful comparison of the fossil floras and faunas from the two states.

Paleontology is not merely of negative value, but is of great positive use in guiding exploration and in recognizing geological structures suitable for drilling. A small collection of fossils is obtained from a new locality and among them are certain horizon markers which are always associated with coal. At once the field is explored for this valuable fuel. In this way, the exploring oil or coal geologist is able to pick out likely areas, and he need not spend time in hopeless regions of volcanic rocks or barren sedimentary beds.

In oil-well drilling many times the bits bring up very small but determinative fossils, and sometimes the only evidence of the underlying structure is obtained in this way. Near Topila, Mexico, in the Anderson well, many small fossils were collected in this maner from a depth of 1,800 feet (550 meters). From a study of this fauna the writer concluded that the rocks containing this assemblage were upper Eocene in age and were essentially equivalent to beds outcropping in the United States Gulf region many kilometers distant but not exposed on the surface in that part of Mexico. This discovery indicated the probable depth of possible production in this territory and was economically important on this account.

Again, in a wild-cat well near Waldorf, California, the bit brought up several small fossil snails, all of the same species, from a depth of 2,000 feet (610 meters). These small snails, not over 1 centimeter long, proved to be *Bittium camulosensis*, a characteristic fossil of the San Fernando Pliocene. Now, the oil in this region generally occurs below this formation, well down in the Vaqueros of Middle Miocene age. The locators thought they started in the Miocene at the surface, but this indisputable evidence indicated that they were mistaken in this regard and either that they had still from 900 to 1,200 meters to go (an impossible depth for economic production) or that a great fault occurred near this well site! The well was abandoned.

As will be shown later in this paper, the fossil clams and snails occurring in the Tertiary enable us to correlate some of these beds with the oil-bearing horizons of Java and Sumatra. This correlation clearly indicates broadly that there are possibilities of economic production of petroleum in the Philip-

pines. In such a manner are broad geological explorations guided by paleontology.

Many volumes of Earth's Books of Rock are missing in the stratigraphic record of the Philippines, and of the individual books complete chapters are missing or so badly mutilated by subsequent earth movements—the geologic scribes—that their deciphering is extremely difficult. The Archaean and Paleozoic sets are entirely missing. Of this great library of Earth's Geologic History, only a small fragment of the Mesozoic set is known, and even in the Tertiary only the Miocene and Pliocene prints are fairly readable. Much of the Pleistocene volume, the last of this wonderful history, is yet to be pieced together, although it is fresh from the Graver's hands.

BRIEF REVIEW OF THE IMPORTANT PALEONTOLOGICAL LITERATURE

Baron Richthofen[1] first reported some interesting Foraminifera from Binangonan Peninsula and referred to them as *Nummulites* with an assignment of the beds yielding them to the Eocene. Later Abella[2] referred certain limestones in Cebu to the Eocene as they likewise contained supposed *Nummulites*. Felix Karrer[3] described some Foraminifera from Zambales Mountains and recognized the Miocene age of the tuffs yielding them. Martin,[4] in a very excellent paper, laid the first firm foundation for Philippine paleontology by recognizing *Vicarya callosa* Jenkins and its associated fauna in Miocene beds of Cagayan Valley and the vicinity of Aringay, La Union. His recognition of Pliocene in Agusan Valley on apparently very scanty evidence really indicated his great grasp of Malayan paleontology and geology. W. D. Smith[5] reviewed the question

[1] Richthofen, Ferdinand von, Vorkommen der Nummulitenformation in den Philippinen, Zeitschr. d. deutschen geol. Ges. 14 (1862) 357–360. Cf. Sobre la formacion numulitica del Japon y de Filipinas (1862).

[2] Abella y Casariego, Enrique, Rapida descripción física, geológica y minera de la isla de Cebu. Madrid, Tello (1886) 187, 6 pls., 1 map. Also Bol. de la Com. del Mapa geol. de España 13 (1886).

[3] Karrer, Felix, Foraminiferos de las margas terciarias de la isla de Luzon (Filipinas), Bol. de la Com. del Mapa geol. de España 7 (1880) 257–282, 2 pls.

[4] Martin, Karl, Ueber tertiäre Fossilien von den Philippinen, Samm. des geol. Reichs-Museums in Leiden 5 (1896) 52–69, 2 cuts. Translation, Becker, Geology of the Philippine Islands, Annual Rep. U. S. Geol. Survey 21[3] (1901) 493–644. See also Orbitoides von den Philippinen, Centralbl. f. Mineral., Geol. u. Paleon. (1901) No. 11.

[5] Smith, Warren Dupré, Orbitoides from the Binangonan limestone, etc., Philip. Journ. Sci. 1 (1906) 203–209, 2 pls.

of the age of the Binangonan limestone and showed that the foraminiferal limestone did not contain *Nummulites* but larger species which he described as *Orbitoides.* Douvillé [6] referred these forms to *Lepidocyclina.* Smith [7] also recognized *Vicarya callosa* in the Batangas Peninsula and described several other forms associated with this guide fossil. Later this same writer [8] described more new fossils from the Philippines and figured some characteristic species. In an economic report by Pratt and Smith, Smith [9] determined the species in the various horizons and figured the species collected from the beds. Two years ago H. Yabe,[10] of the Tohoku Imperial University of Japan, published a careful discussion of *Lepidocyclina* of the Philippines and illustrated several new species of this genus most excellently. The present writer [11] recently discussed the Vigo fauna and its bearing upon the rate of evolution of Mollusca in the Tropics.

MESOZOIC

W. D. Smith [12] first recognized in certain cherts and slates in Ilocos Norte unicellular forms, Radiolaria, which appear to be of probable Jurassic, Middle Mesozoic, age. Concerning these rocks Smith says:

> In Ilocos Norte, Pangasinan, Balabac, Panay, and other localities there are outcrops of hard, red cherts or jaspers, in some places as hard, structureless bowlders and in others as fissile beds. When I first found these in Ilocos Norte, I compared them with the cherts of California. On examination with a microscope they were found to contain fragments of radiolarian tests. These rocks have a wide distribution in this part of the world, and have been provisionally assigned to the Jurassic by Martin.[13]

[6] Douvillé, H., Les foraminiféres dans le Tertiaire des Philippines, Philip. Journ. Sci. § D 6 (1911) 53–80, 4 pls.

[7] Smith, W. D., Preliminary geological reconnaissance of the Loboo Mountains of Batangas Province, Philip. Journ. Sci. 1 (1906) 617–633, 4 pls.

[8] Smith, W. D., Contributions to the stratigraphy and fossil invertebrate fauna of the Philippine Islands, Philip. Journ. Sci. § A 8 (1913) 235–300, 20 pls.

[9] Pratt, Wallace E., and Smith, Warren D., The geology and petroleum resources of the southern part of Bondoc Peninsula, Tayabas Province, P. I., Philip. Journ. Sci. § A 8 (1913) 301–376, 10 pls., 1 map.

[10] Yabe, H., Notes on Lepidocyclina limestone from Cebu, Science reports of the Tohoku Imperial University, Second series (Geology) 5 [2] (1919) 37–51, 2 pls.

[11] Dickerson, Roy E., A fauna of the Vigo group; its bearing on the evolution of marine molluscan faunas, Philip. Journ. Sci. 18 (1921) 1–23, 2 pls.

[12] Smith, W. D., Philip. Journ. Sci. § A 8 (1913) 245, 246.

[13] Martin, K., Reisen in den Molukken I. Leiden (1903) pt. 3.

In certain localities in Borneo rocks of proved Upper Cretaceous age rest uncomformably upon the older radiolarian beds, so it is clear that the upper possible limit, Lower Cretaceous, is fixed for these cherts. Hinde [14] compares the species of Radiolaria with radiolarian faunas elsewhere and concludes that their age is Jurassic.

Smith reports the same rocks from the western cordillera of Panay and from Bulacan Province, Luzon. At the latter place he made slides from material collected by Mr. Frank A. Dalburg and recognized the Radiolaria *Cenosphaera affinis* Hinde and *Dictyomitra tenuis* Hinde. The photomicrographs given in Plate 1 illustrate these interesting marine forms.

Similar forms have been described by Hinde in the appendix to Molengraaff's Explorations in Borneo.

The stratigraphic evidence of the relative age of these rocks in the Philippines is lacking, but the geographic distribution of similar rocks in the Moluccas and Borneo indicates that they all represent the same period. Unfortunately the Radiolaria have a rather great geological range and on this account only a tentative assignment to the Jurassic is possible.

No Cretaceous rocks have been recognized in these Islands, although the Cretaceous is well developed in Japan.

TERTIARY

The lowest portion of the Tertiary, the Eocene—the dawn of modern life—has also not been recognized with certainty in the Philippines, although rocks of this age occur in Japan to the north and Java to the south.

The genus *Nummulites* in many regions is characteristically Eocene, but in the East Indies this genus is not so restricted. The type locality of *Nummulites subniasi* Douvillé is in limestone associated with coal measures of Batan Island. This form, according to Douvillé, is equal to *Nummulites variolaria* Brady from Nias Island, which is located near the west coast of Sumatra. This species, according to Brady, is associated with *Nummulina ramondi*, *Orbitoides papyracea*, and *Orbitoides dispansa*, in Sumatra. The form identified by Brady as *Orbitoides papyracea* was later shown to be distinct from this species and

[14] Hinde, G. J., Appendix on fossil Radiolaria of Central Borneo in Molengraaff, G. A. F., Geological explorations in Central Borneo. Society for the Promotion of the Scientific Exploration of the Dutch Colonies, Leyden (1893–94).

on this account was described under the name of *Lepidocyclina verbeeki* by Newton and Holland.[15]

Lepidocyclina verbeeki Newton and Holland occurs in the upper limestone above the coal in Cebu, a horizon of probable Miocene age. Thus it is that the general association and connections of *Nummulites subniasi* Douvillé are not with Eocene species but with Miocene.

That Eocene beds may be present is a possibility, but as yet they have not been recognized. Likewise, horizons of Oligocene age are not positively known. In certain localities, Eocene and Oligocene times are represented by a mere line of unconformity between the basement complex of diorites and associated schists and the sedimentary rocks of Miocene age. In other words, a portion of the Philippines was a land mass during Eocene time, and on this account no marine sedimentary beds of Eocene age occur in certain regions.

MIOCENE

VIGO GROUP[16]

Rocks of Miocene age have been recognized in most of the larger islands of the Philippines, and owing to their widespread occurrence this period of the Tertiary is best known. Since both oil and coal occur in these rocks, their paleontology is of particular economic importance. The rocks of the Vigo group exhibit two pronounced faunal facies. One occurs in limestone and is characterized by large unicellular forms, Foraminifera of the genus "Lepidocyclina," while the other facies consists principally of clams and snails which lived in the sandy or muddy, moderately deep waters of an inland Miocene sea.

PELECYPODS AND GASTROPODS OF THE VIGO GROUP, SANDSTONE AND SHALE FACIES

The pelecypods and gastropods of the Miocene are best known from Bondoc Peninsula, Luzon Island. At many places in the

[15] Newton and Holland, On some Tertiary Foraminifera from Borneo, Ann. & Mag. Nat. Hist. VII 7 (1901) 215.

[16] The writer is not in agreement with Pratt and Smith concerning the stratigraphic relations of the Malumbang, Canguinsa, and Vigo in their type localities, the Bondoc Peninsula. He believes that a great unconformity exists between the Malumbang and the underlying Vigo group. He failed to recognize an unconformity between the Canguinsa formation and the Vigo shale, although the areas cited by Pratt and Smith were critically examined. The relations that appear at these places are best explained by faulting. On this account the term "Vigo" is widened to include the Canguinsa formation as its upper sandstone facies, thus raising the term Vigo to a group rank.

southern half of this peninsula excellently preserved fossils have been collected from the Canguinsa formation, the upper horizon of the Vigo, and from the underlying shales of this group. A partial list of these species follows.

Partial list of species from the Vigo group.

Architectonica pictum (Philippi).
Actaeon reticulatus K. Martin.
Buccinium simplex K. Martin.
Bullaria ampulla (Linnæus).
Cancellaria crenifera Sowerby.
Cancellaria elegans Sowerby.
Cassidaria.
Cerithium jenkinsi K. Martin.
Cerithium herklotsi K. Martin.
Cerithium moniliferum Kiener.
Cerithium bandongensis K. Martin.
Cerithium sp. nov.
Cerithium jonkeri K. Martin.
Cerithidea cf. *ornata* Hinds.
Cerithidea (*Pyrazus*) cf. *sulcatus* Bruguiere.
Cerithidea cf. *quadrata* Sowerby.
Conus ornatissimus K. Martin.
Conus sp. nov.?
Conus sp.
Conus lividus Hwass.
Conus loroisii Kiener.
Conus hardi K. Martin.
Conus striatellus Jenkins.
Columbella bandongensis K. Martin.
Cyclonassa elegans Kiener.
Cypraea cf. *tigris* Linnæus.
Cypraea sp.
Drillia sp.
Delphinula?
Delphinula reeviana Hinds.
Distortio clathrata Lamarck.
Eburna ambulacrum Sowerby.
Ficus reticulata (Lamarck).
Haminea.
Harpa articularis Lamarck.
Mitra javana K. Martin.
Mitra cf. *jenkinsi* K. Martin.
Mitra junghuhni K. Martin.
Mitra bucciniformis K. Martin.
Mangelia.
Murex endivia Lamarck.
Marginella.
Melania asperata Linnæus.
Melania asperata inquinata Quadras.
Nassa crenulata (Bruguiere).
Nassa dispar Adams.
Nassa gemmulata (Lamarck).
Nassa globosa minor Quoy.
Nassa thersites immersa Carpenter.
Nassa thersites leptospira (Bruguiere).
Nassa quadrasi Hidalgo.
Nassa canaliculata Lamarck.
Nassa costellifera A. Adams.
Nassa reussi K. Martin (may = *N. costellifera*).
Natica albumen Lamarck.
Natica?
Natica spadicea Reeve.
Natica mamilla Lamarck.
Natica lacernula d'Orbigny.
Natica cumingiana Recluz.
Nerita funiculata Reeve.
Olivella.
Phos roseatus Hinds.
Ranella.
Ranella subgranosa Beck.
Ranella tuberculata Broderip.
Ricinula spectrum Reeve.
Rostellaria fusus Linnæus.
Rostellaria crispata Kiener.
Strombus canarium (Linnæus).
Strombus, sp. a.
Strombus, sp. b.
Strombus swainsoni Reeve.
Strombus (?) *fusus* K. Martin.
Strombus (?) sp.
Turris (*Surcula*) *flavidula* Lamarck.
Turris garnonsi Reeve.
Turris deshayesi (Doumet).
Turris carinata woodwardi K. Martin.
Turris coronifer (K. Martin).
Turris marmorata (Lamarck).
Terebra bicincta K. Martin.

Partial list of species from the Vigo group—Continued.

Terebra javana K. Martin.
Terebra.
Triton pfeifferianum Reeve.
Trochus.
Telescopium telescopium Linnæus.
Trivia smithi K. Martin.
Voluta cf. *innexa* Reeve.

PELECYPODA

Arca cornea Reeve.
Arca ferruginea Reeve.
Arca granosa Linnæus.
Arca cf. *coelata* Reeve.
Arca tenebrica Reeve.
Barbatia fusca (Bruguiere).
Cardium.
Cardium attenuatum Sowerby.
Cardium donaciformis Cuming.
Cardium unicolor Sowerby.
Cardita antiquata Linnæus.
Chione chlorotica Philippi.
Chione?
Corbula scaphoides Hinds.
Corbula socialis K. Martin.
Clementia hyalina Philippi = *C. papyracea.*
Dosinia cf. *lenticularis.*
Dosinia cretacea Philippi.
Glycimeris viteus (Lamarck).
Glycimeris angulatus (Lamarck).
Ostrea.
Paphia textrix Deshayes.
Pecten (Pleuronectia) pleuronecta Linnæus.
Pecten cf. *radula* Linnæus.
Pecten cf. *pseudolima* Sowerby.
Pecten pseudolima Sowerby.
Pecten cf. *cristularis* Adams and Reeve.
Placuna placenta Linnæus.
Psammobia cf. *lessoni* Blainville.
Psammobia sp.
Pinna sp.
Solen sp.
Spisula sp.
Solecurtus quoyi Deshayes.
Spondylus sp.
Tellina sp.
Tellina sp.
Vermetus javanus? K. Martin.
Vermetus sp. nov.

In the above list about 75 per cent of the specifically determined forms are living species, an astonishing percentage when the geologic history of the region yielding these forms is considered. The extinct forms are practically all common to the upper Miocene of Java according to K. Martin, [17] and they are practically all highly organized species. Such highly developed species are particularly fitted to their surroundings, and a slight change in life conditions might cause the extinction of the species or bring about a specific change.[18] As was noted above, the percentage of Recent species is remarkably high, and it is the writer's conclusion from a detailed study of the subject that the evolution of marine molluscan faunas in the Tropics is far slower than in the Temperate Zones. On this account the same "yardstick" in the Tertiary geological time scale cannot be applied in both tropical and temperate regions. The scale used in the Temperate Zones is approximately as follows: Eocene, 0 per cent living species but practically all genera living; Oligocene, 3 per

[17] Martin, K., Tertiärschichten auf Java. Leiden (1880) 44–51.
[18] Dickerson, R. E., Philip. Journ. Sci. 18 (1921) 1–23. This subject is discussed in detail in the paper cited.

cent living species; Miocene, 25 per cent; Pliocene, 60 per cent; Pleistocene, 90 per cent. It is the writer's opinion that this percentage scale in the Tropics must be considerably widened.

On this account the careful determination of guide fossils is of great economic importance. Good guide fossils are far more difficult to select in connection with tropical Tertiary faunas of the Philippines than in the California Tertiary, owing to the great predominance of Recent Mollusca. As will be seen from a study of the fauna cited above, most of the forms which are extinct were originally described from a correlative horizon in Java. Of these, the writer is inclined to think that *Cerithium jenkinsi, C. herklotsi, C. bandongensis, Mitra javana, M. jenkinsi, M. junghuhni, M. bucciniformis, Turris coronifer, Terebra bicincta, T. javana, Vicarya callosa,* and *Vermetus javanus* will probably prove reliable guides among the Mollusca. These species are all representatives of highly organized genera, and their extinction during post-Miocene time was probably due to their inability to obtain life conditions suited to their highly specialized needs.

Corals, echinoderms, and the more highly organized Foraminifera will probably prove to be even better horizon determiners, but their comparative infrequence in strata of the Philippines will at times preclude their use. The writer has not yet attempted to identify the corals and the echinoderms in the collections made, but their value will no doubt prove to be great. It seems that their rate of evolution may have been greatly retarded, but much study will be required in this connection. For stratigraphic work in the Tropics large and complete collections are necessary for obtaining results of much value, in as much as the geologic and paleontologic history, even with the best data available, is read with much difficulty. Much comparative material, both Recent and fossil, should be accumulated, as subspecific differences will be recognized only through comparative studies. These subspecific differences are exceedingly important for minute separation and discrimination of strata deposited under tropical conditions.

Some of the most abundant species and guide fossils for the sandstone and shale facies of the Vigo are illustrated in Plates 2 to 10.

LEPIDOCYCLINA LIMESTONE FACIES OF THE VIGO GROUP

The limestones of the Vigo group are characterized by the abundance of the large foraminifer *Lepidocyclina,* associated with other Foraminifera. This limestone is in certain places

stratigraphically associated with sandstones and shales which have yielded a typical Vigo fauna. The best region for the study of this facies is in Cebu Island, where the limestone which overlies the coal at Danao has yielded several species of these interesting and important unicellular forms. According to Douvillé,[19] these beds represent the middle horizon. Douvillé states that the study of Foraminifera permits him to make the following subdivisions:

I. The lower lignitic horizon is characterized by the association of genera *Nummulites* and *Lepidocyclina*.

II. The middle horizon is characterized by the abundance of *Lepidocyclina* and the presence of *Alveolina*.

III. The upper horizon has an abundance of small *Lepidocyclina* and *Miogypsina*. Douvillé states that this same succession occurs in Borneo and Indo-Asia. He correlates the lower horizon with the Stampian, Oligocene; the middle, with the Aquitanian, Lower Miocene; the upper, with the Burdigalian, Miocene. In a footnote Douvillé states that in conformity with recent work the limit between the Oligocene and the Miocene, or between the Eogene and the Neocene, is placed between the Stampian and Aquitanian, properly limited. Douvillé's conclusions, translated by Mrs. G. B. Moody and Mrs. R. E. Dickerson, are as follows:

From the preceding study the writer is enabled to classify the described beds in the following manner:

Eogene (comprising the Eocene and the Oligocene), Stampian Stage. Limestone of Caracaran (Island of Batan, locality 2).

This is a bluish gray limestone upon which the Foraminifera stand out in black; it is a part of the lignitic horizon and is intercalated between beds of lignite.

The thin plates and polished sections show a small species of *Nummulites* 2.7 millimeters in diameter which appears to correspond to *N. niasi* Verbeek; but this last species is microspheric while that of the Philippines is macrospheric, and has been distinguished as *N. subniasi*. This same limestone also yields *Polystomella* sp. and a curious *Lepidocyclina* belonging in the section *Neophrolepidina*, *L. smithi*, which resembles certain varieties of *L. proemarginata*.

The coexistence of *Nummulites* and *Lepidocyclina* characterize the Stampian; it is noteworthy that these two genera are not represented here except by forms of very small size, although a little farther south in Borneo the large forms are abundant.

II. Neocene (Aquitanian, Burdigalian, Helvetian) Aquitanian Stage.

1st. The soft yellowish sandstone of Sibul Gulch (old Alpaco mine, Island of Cebu, locality 273). The sandstone is incoherent and but slightly

[19] Douvillé, H., Les Foraminiféres dans le Tertiaire des Philippines, Philip. Journ. Sci. § D 6 (1911) 54.

cemented by limestone. The fossils are casts and the internal characters are difficult to recognize. The fauna is essentially composed of *Orbitolites* and *Alveolinella*, with *Operculina costata* var. *tuberculata*, *Rotalia*, *Polystomella*. This bed is indicated as above the coal and below the *Lepidocyclina* limestone. This ought to correspond nearly to the horizon with *Orbitolites* and *Alveolinella* in Java which Mr. Verbeek places as stage m, that is to say, in the lower Aquitanian. Owing to the poor state of preservation of the fossils, this reference is only a provisional one. It is to be noted that Professor Martin announced the discovery by Semper of *Orbitoides* in a mine of Alpaco.

2d. The best characterized horizon is the limestone with the large lepidocyclinas:

Limestone of Guila-Guila (Cebu, locality 278). There occur numerous lepidocyclinas of large size; some present surfaces having well-developed tubercules and these have been referred to *Lepidocyclina insulæ-natalis;* the others with but few if any tubercules have been assigned to *Lepidocyclina richthofeni*. These two forms are very numerous; they are associated with a third species, a much smaller form composed of a central part, very swollen, bordered by a collarette; this is *L. formosa*, nearly free from tubercules, but it presents very thick walls between the chamberlets. These various forms are often found free.

There are places representing this same horizon, the limestones of the Barrio of Mesaba (Cebu locality 272) *L. insulæ-natalis;* those of the valley of Cumajumayan (Cebu locality 28) *L. richthofeni* and *L. formosa;* the two latter forms occur together with a third species, *L. inermis*, which has thin walls between its cells, at Compostela mine (Cebu, locality (289).

3d. There is another horizon probably to be placed slightly higher, a soft limestone bed, cream white in color, which outcrops boldly in great escarpments along the road from Toledo to Cebu, on the edge of the Minanga River (locality 277, near camp 1); this presents upon its surface very well-preserved specimens of *Operculina complanata* and *Cycloclypeus communis;* this bed is correlated with the Silex marls of the Aquitanian of Borneo.

Burdigalian Stage.

This upper horizon is characterized by the appearance of *Miogypsina* and by the abundance of small lepidocyclinas of the section *L.* (*Nephrolepidina*) *verbeeki*. I refer the two following beds to the Burdigalian:

A very soft sandy yellowish limestone of Gaba Bay, Island of Batan (locality 8) above the lignitic beds; there occur well-preserved but fragile forms, among which are *Globigerina*, *Cycloclypeus communis*, *Amphistegina* cf. *mamillata;* and a small *Miogypsina*, the last being referred to a Burdigalian form occurring near Dax (France).

A very soft white limestone which runs along the Cordillera Central of the Island of Cebu, Valley of Cotabato (locality 279); here occurs *L. verbeeki*, which was first described by Mr. Warren D. Smith, but above all it is associated with *L. inflata* and numerous *Miogypsina irregularis*.

Of these three faunas which I recognized, the second is characterized principally by the great abundance of large *Lepidocyclina* which has a very great distribution from Madagascar to the Philippines. I recognized in my study upon the Foraminifera of the Tertiary of Borneo that they correspond to the Aquitanian; I have distinguished three horizons, E, F, G, which it ought to be possible to find in the Philippines when geological explorations are more advanced.

The upper horizon Burdigalian H (of Borneo) also presents a very great distribution; it is well developed in the island of Nias, near Java, from whence comes the type of *L. verbeeki*, and from Borneo where I have not been able to distinguish this species from the similar European form *L. tournoueri*. This same horizon appears to extend to the north in Formosa and Japan in the environment of Tokyo. This last locality is in latitude 36°, that is to say, near that of Gibraltar; however, the *Lepidocyclina* occur in France nearly to latitude 44° and beyond 45° in Italy.

The following table summarizes the references which I recognize:

Philippines.			Borneo.
II.	Upper limestones with small Lepidocyclinas.	L. verbeeki, Miogypsina, Cycloclypeus communis	H. Burdigalian.
	Middle limestone	Cycloclypeus communis Operculina complanata	G. Aquitanian.
	Lower limestones with large Lepidocyclinas.	L. insulæ-natalis	F. Aquitanian.
		L. richthofeni L. formosa	E. Aquitanian.
I.	Lignitic horizon and lower limestones with Nummulites.	Nummulites subniasi Amphistegina niasi Lepidocyclina smithi	D. Stampian.

In Europe the succession of faunas is very analogous; the lepidocyclinas are well developed, moreover, likewise in Spain, as well as Italy, where they attain a great size and are associated as in Borneo with reticulated *Nummulites*. The section of which *Lepidocyclina dilatata* is an example corresponds to the Asiatic section of *L. insulæ-natalis* and extends into the Aquitanian. Moreover, in the upper beds the section of *L. tournoueri* is represented by that of *L. verbeeki*. With these two are associated, moreover, *Miogypsina*.

The European basin and the Asiatic basin appear to have been completely separated at the end of the Eocene by the uplift of Lybia which was developed across the Mésogée and separated the Mediterranean from the Indian Ocean. It is only during very recent time that the Red Sea has almost reëstablished a communication between the two seas, but the waters of the Indian Ocean are even now several kilometers separated from the Mediterranean by the slight barrier of the Isthmus of Suez.

The limestones referred by Douvillé to the Stampian, as stated by him, occur between coal seams in Batan Island. At this locality or in its near vicinity in the gray shale overlying the East Batan coal seam in the Perseverancia claim very excellent specimens of *Vicarya callosa* Jenkins and numerous species of *Corbula* were obtained by Mr. F. A. Dalburg (Bureau of Science locality 7). *Vicarya callosa* Jenkins is regarded by Martin and other workers as being one of the best horizon markers of Middle and Upper Miocene in the East Indian islands. In this connection Smith states:[20]

[20] Smith, W. D., Philip. Journ. Sci. § A 8 (1913) 268.

This species is moderately common in the Philippine coal measure shales, being especially plentiful in the shale above the principal coal seam on the eastern end of Batan Island, Albay Province. It is also found in the same position in the coal measures in Cebu and Mindanao.

On this account it seems to the writer that the above reference to the Oligocene is very questionable, and it is his opinion that this Batan coal is of essentially the same age as is the coal of Cebu and tunnel 14 of Sibuguey Peninsula, Mindanao. At the latter place, Mr. F. A. Dalburg recently collected splendid specimens of *Vicarya callosa* Jenkins from the coal seams and shales. (See Plate 6, fig. 1*a*.) Now *Vicarya callosa* is associated with the coal seams of Cebu and seems to be a form which flourished in brackish water. Whether this form is very limited in geologic range is probably open to question, as those forms which have a great geographic distribution frequently have a considerable stratigraphic range as well. It is probably limited to the Vigo group at least, that is, to about 3,000 feet of sedimentary beds, as it never has been reported from the Malumbang formation.

Douvillé places locality 272 in his II, 2, the *Lepidocyclina* limestone. The Bureau of Science possesses an excellent collection of gastropods and pelecypods from this place, and the following forms have been identified:

Bullaria ampulla (Linnæus).
Conus sp.
Cerithium (*Campanile*) sp.
Cerithium sp.
Cerithium jenkinsi K. Martin.
Cerithium herklotsi K. Martin.
Cypraea sp.
Chione lacerata Hanley.
Fusinus sp.
Natica sp.
Lucina sp.
Pecten cf. *lentiginosus* Reeve.
Pecten leopardus Reeve.
Plicatula imbricata Menke.
Turbinella junghuhni K. Martin.
Trochus sp.
Turbo sp. a.
Seraphs sp.
Vicarya callosa Jenkins.
Voluta innexa Reeve.

A brief comparison of these forms with collections from the Vigo group of Bondoc Peninsula clearly demonstrates essential faunal unity.

W. D. Smith[21] reported some of the large foraminifers from Bondoc Peninsula from beds of Canguinsa age. He says:

The limestone from Mount Morabi (fossil locality 62) contains *Cycloclypeus communis* K. Martin, which represents the middle Miocene, and large lepidocyclinas some of which are 45 millimeters in diameter and 5

[21] Pratt, W. E., and Smith, W. D., Philip. Journ. Sci. § A 6 (1913) 330.

millimeters broad in the thickened central portion. * * * This species has been referred by Douvillé to the lower Miocene.

This *Lepidocyclina* fauna occurs in the upper portion of the Vigo group, the Canguinsa formation. This formation, in this same region, has yielded a large part of the mollusks reported above, and it is clear that the vertical range of the large representatives of the genus *Lepidocyclina* is much greater than Douvillé suspected.

H. Yabe,[22] in a recent publication, recognizes this possibility and he reviews the case as follows:

L. Rutten studied foraminiferal rocks from southern and eastern parts of Borneo and found it necessary to modify somewhat H. Douvillé's correlation of the Tertiary rocks, because *Lepidocyclina* appeared to him to have a more extended vertical range than was believed by Douvillé. Thus the oldest Miocene and Oligocene deposits, according to Rutten are characterized by Lepidocyclinas of larger and smaller sizes, while the smaller ones alone are found together with Miogypsina in all parts of Miocene deposits except the lowest division.

Rutten [23] presents a table in his paper which is copied by Yabe. Yabe,[24] in another and later paper upon the *Lepidocyclina* limestone from Cebu, recognized *Lepidocyclina* (*Nephrolepidina*) *angulosa* Provale associated with *Lepidocyclina monstrosa* Yabe, *Lepidocyclina formosa* Schlumberger, and several other Foraminifera. It is evident from this assemblage that the section *Nephrolepidina* is not restricted to the uppermost horizon, as Douvillé thought.

Briefly, in conclusion, then, the *Lepidocyclina* limestone is equivalent to the shales and sandstones of the Vigo group, and the molluscan faunas of the latter beds are equivalent to the large-sized *Lepidocyclina* fauna of Cebu. In other words, the limestones, shales, sandstones, and coal are different depositional facies within the same group, the Vigo of probable Middle and Upper Miocene age.

The corals of the Vigo group are not well known, and many forms await careful description. In general, the corals of this group are either individual or slender branching forms, and this

[22] Yabe, H., Notes on a Carpenteria limestone from B. N. Borneo, Science Reports Tohoku Imperial Univ. II 5 [1] (1918) 2.

[23] Rutten, L., Studien über Foraminiferen aus Ostasien, Samml. d. Geol. Reichsmuseum I 9 (1911–1914) 287.

[24] Yabe, H., Notes on a Lepidocyclina limestone from Cebu, Science Reports Tohoku Imperial Univ. II 5 [2] (1919) 1.

characteristic is in great contrast with the coral fauna of the overlying Malumbang formation where the dominant forms are the large reef-building types with many large heads.

Smith[25] reports *Pattalophyllia* (?) *bonita* Smith, *Pachyseris cristata* K. Martin, and *Madrepora duncani* Reuss (?) from Bureau of Science locality 272, Barrio Mesaba, near Danao, Cebu, where they are associated with the large forms of *Lepidocyclina* and the Mollusca listed above from the same locality. *Pachyseris cristata* and *Madrepora duncani* are reported by Martin from locality P, where they are associated with *Vicarya callosa* and its characteristic molluscan associates.

FAUNA OF THE MALUMBANG FORMATION

Like the Vigo group, this formation of probable Pliocene age is very widespread throughout the Philippine Archipelago. Both lithologically and faunally this formation is in sharp contrast with the Vigo described above. The Malumbang corals, for example, are nearly all reef builders, colonial forms, while the Vigo corals are chiefly simple individual or slender branching forms. In the case of the Malumbang, these large colonial forms make the coralline limestone which is characteristic of this formation at its type locality, the Malumbang Plain and Banaba Ridge vicinity in the southern end of Bondoc Peninsula, Tayabas Province, Luzon. Since this formation is best known at its type locality, most of the present discussion is based upon material secured from that region. Pratt and Smith[26] discuss the Malumbang fauna at the type locality of the formation and give lists of species which the present writer has slightly modified. They state conditions as follows:

> All three horizons in the Malumbang series are fossiliferous. Fossils were collected at two places on the hills at the northern edge of Malumbang Plain, which are capped by the Upper limestone. Specimens from fossil locality 61 were obtained on the hills north of Mount Anuing near the eastern rim of Canguinsa River valley at Bacau, and others (fossil locality 63) were found on the hills immediately to the east on the northern border on Malumbang Plain. The Upper limestone in this vicinity is sandy, and grades imperceptibly into the Cudiapi sandstone below it. The fossils are embedded in sandy, calcareous material which might be designated either as sandstone or limestone.

[25] Smith, W. D., Contributions to the stratigraphy and fossil invertebrate fauna of the Philippine Islands, Philip. Journ. Sci. § A 8 (1913) 285–291.

[26] Pratt, W. E., and Smith, W. D., The geology and petroleum resources of the southern part of Bondoc Peninsula, Tayabas Province, P. I., Philip. Journ. Sci. § A 8 (1913) 325–327.

Fossils collected at locality 61.

Pecten senatorius Gmelin. +	*Operculina costata* d'Orb. +
Pecten leopardus (?) Reeve. +	*Conus* sp.
Cytherea sp.	*Olivia* indet.
Cardium sp.	*Strombus labiosus* Gray. +
Schizaster subrhomboidalis Herklots.	*Melania* sp.
Xenophora dunkeri K. Martin. (?)	*Dosinia* sp.
Turbo sp.	*Lagenum multiforme* K. Martin var. *tayabum* Smith.
Conus sp.	*Turbo* sp.
Pecten senatorius Gmelin. +	*Trochus* sp.
Mitra sp.	*Bulla ampulla* Linn. +
Xenophora sp.	*Olivia* sp.
Spondylus imperialis Chem. +	*Pattalophyllia* sp. +

Of the determinable fossils in these and the following lists, those which represent living species are indicated by a plus sign.

Fossils were obtained from the Cudiapi sandstone at three different places, as follows: (1) Fossil locality 65, calcareous sandstone immediately beneath the Upper limestone in the hills north of Malumbang Plain, adjacent to fossil locality 61; (2) fossil locality 4, calcareous sandstone beneath the Upper limestone about 450 meters south of Balinsog Hill, at an elevation of 360 meters; (3) fossil locality 13, sandstone, at an elevation of 270 meters on the high ground between Apad and Milipilijuan Creeks, affluents of the Bahay River. The Upper limestone does not occur over the sandstone at this place, but the sandstone itself is very calcareous.

The fossils from the Cudiapi sandstone were determined as follows:

From fossil locality 65.

Dosinia sp.	*Schizaster subrhomboidalis* Herklots.
Pecten sp.	

From fossil locality 4.

Turbo sp.	*Pleurotoma* sp.
Nassa sp.	*Melania* sp.
Fusus sp.	

From fossil locality 13.

Clementia sp.	*Cerithium herklotsi* K. Martin.
Xenophora dunkeri K. Martin.	*Pleurotoma tjemoroënsis* K. Martin.
Ostrea orientalis Chemnitz. (?) +	*Pleurotoma carinata* Gray. +
Pecten senatorius Gmelin. +	

Fossils from limestone at a horizon corresponding stratigraphically with that of the Lower limestone were collected at three localities, namely: Fossil locality 44, at the mouth of Ayoni [Yuni] River; fossil locality 59, on a prominent hill (elevation, 250 meters) 2 kilometers west of Tala; and fossil locality 25, near Tambo, a barrio of San Narciso. However, as will appear in the discussion of the field relations at these localities, only the last group in the foregoing list represents certainly the Lower limestone; the fossils from the other localities may belong to either the Upper or Lower limestone.

On the north side of Ayoni [Yuni] River near its mouth, fossils were found in the limestone which forms the ridge along the western coast of the peninsula.

Fossils collected at locality 44.

Cypraea sp.
Arca nodosa K. Martin. (?)
Schizaster sp.
Cerithium sp. large internal cast.

Along the western coast from Ayoni [Yuni] north to Catanauan, this limestone is found in the coastal ridge, and occurs conformably only a short distance above beds which clearly belong to the Vigo shale. A short distance inland from Ayoni similar limestone occurs above the Canguinsa sandstone, and is overlain at places by the Cudiapi sandstone. This relation suggests that the limestone at Ayoni is the Lower limestone, but the evidence is not conclusive and either limestone horizon may be represented by the fossils from this locality.

Fossils collected at locality 59.

Pyrula gigas K. Martin.
Balanus sp.
Pecten leopardus K. Martin.

The limestone in which these fossils were found occurs on the top of a hill; below the limestone, with a concealed interval between, the Canguinsa sandstone was observed. The thickness of the concealed beds is hardly great enough to include the Cudiapi sandstone and the Lower limestone in their usual thicknesses. The fossils, therefore, are assigned to the Lower limestone, although they may represent the Upper limestone instead.

A sample of limestone (fossil locality 25), which certainly came from the Lower limestone horizon, was collected near the Cabongahan-San Narciso trail at an elevation of 180 meters, on the east side of the ridge extending northwest from Mount Cambagaco. Thin sections of this rock show small fragments of limestone and the well-known alga, *Lithothamnion ramosissimum* Reuss, intermingled in a cement of calcite.

The molluscan fauna of this formation is very sparse when compared to that of the Vigo group. This is in part due to poor preservation (as the surface waters readily penetrate the coralline limestones, marls, and sandstones) and in part due to original life conditions of deposition. The molluscan fauna living on coral reefs in these Islands to-day is not characterized by a great variety of forms, and since much of the sediment of the Malumbang was laid down as Pliocene coral reefs the molluscan assemblages found in these coralline limestones or their derivative marls consist of relatively few species.

State of preservation is no guide at all in determining the age of faunas in the Philippines. Vigo forms are often as well preserved as is beach material, while the much younger Malumbang fossils are frequently badly decomposed. Even Pleistocene species secured from raised coralline limestone beaches are much older in appearance than Vigo forms. On this account, the field man should be especially careful not to permit state of

preservation to influence his judgment in determining the relative age of any stratum he may study.

The best collecting locality yet found in the Malumbang was discovered by Mr. E. W. McDaniel, who assisted the writer in making a good collection here. This locality is described as follows:

Locality 1x, Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, west side of Ragay Gulf, 2.75 kilometers northwest of Bureau of Lands bench mark No. 1, in coarse sandstone (coral and shell sand) dipping 12° south, strike north 50° west. Collectors, E. W. McDaniel and Roy E. Dickerson.

The following species have been identified from this locality. The species still living in these seas to-day are marked by L.

Partial list of species from locality 1x.

Fungia sp.
Schizaster subrhomboidalis Herklots.
Clypeaster sp. a.
Clypeaster sp. b.
Arca ferruginea Reeve. L.
Arca cornea Reeve. L.
Arca sp.
Aspergillum annulosum Deshayes. L.
Cardium sp.
Cardita antiquata Linnæus. L.
Dosinia variegata Reeve. L.
Glycimeris sp.
Glycimeris multistriatus (Deshayes). L.
Modiolus sp.
Mytilus sp.
Macoma sp.
Metis sp.
Ostrea hyotis Linnæus. L.
Pecten leopardus Reeve. L.
Pecten exaratus K. Martin.
Pecten sp.
Placuna placenta Linnæus. L.
Pinna sp.
Spondylus imperialis Chemmitz. L.
Tellina sp. a.
Tellina sp. b.
Conus ornatissimus (variety) K. Martin.
Dolium costatum Menke. L.
Natica sp.
Turbo sp.
Turritella sp.
Leucozia cf. *unidentata* de Haan. L.

The high percentage of Recent species is noteworthy and is in accord with the writer's general conclusions based upon a study of the Vigo fauna.

The corals from the Malumbang formation have not received the careful attention which they deserve, and undoubtedly many important conclusions will be derived from this study. Students of the coral-reef problem may here obtain much material for study, as both Pleistocene and Recent coral reefs occur in this tropical Archipelago as well as in these older beds.

Father Francisco de P. Sanchez, of Ateneo de Manila, recently loaned to the Bureau of Science his collection of fossil corals obtained from the coralline limestones near Mount Mirador Observatory, Baguio, Benguet, Mountain Province. From a

cursory study of this collection it is apparent that several of the species are identical with the reef corals collected from the Malumbang Pliocene at its type locality in the Bondoc Peninsula.

Concerning the coralline limestones of this general region, von Drasche says:[27]

There can be no doubt that the coralline limestones belong to the most recent rocks occurring in northern Luzon. They always form the uppermost member of all formations, and with the exception of Benguet, where they are covered with a thin layer of red earth, I failed to find these limestones beneath other rocks. As has been said, they contain a number of coral fragments which, unfortunately, are in a poor state of preservation; they contain, although only in limited numbers, remains of lamellibranchs, gastropods, echinoderms, etc. All of these fossils have, however, suffered very much on account of the crystallization of the limestone.

A more extensive examination of the same material undertaken by me in conjunction with my honored friend Doctor von Marenzeller, in charge of the collection of the Zoölogical Court Cabinet, led also to substantially the same results.

Even though it was impossible to give a reliable specific report on account of the poor state of preservation of the fossils, it nevertheless was possible for us to declare with certainty that, with the exception of one single piece, which we could not identify, all of the rest belonged to genera which occur to-day in great abundance in the Indian Ocean, and even the individual corals can be referred without any question to living types. The corals examined do not show the least relationship to the Tertiary corals from Java described by Reuss.

Regarded from this point of view, the raised coral reefs of Luzon must be considered as very recent in origin.

The genera identified by us are the following: *Galaxaea* sp., *Favia* sp., *Maeandrina* sp., *Porites* 2 sp., (?) *Astraeopora* sp.

The stratigraphic as well as the paleontologic results go to show that the raised coral reefs of Luzon belong to the most recent geologic formation.

Stratigraphic confirmation of the paleontological correlation of the Mount Mirador limestone with the Malumbang formation was recently obtained by Mr. H. P. Whitmarsh, who collected excellent specimens of *Vicarya callosa* Jenkins, a species characteristic of the Vigo group of Miocene age, from sandstones, lignites, shales, and shaly limestones which dip at an angle of 35° beneath the coralline limestones of Mount Mirador belt. This locality is about 6 kilometers west of Baguio and about 450 meters south of the Naguilian road which runs

[27] Copied from King's translation of Von Drasche's Fragmente zu einer Geologie der Insel Luzon. Wien (1878) 36–46. See Smith's Notes on a geologic reconnaissance of Mountain Province, Luzon, P. I., Philip. Journ. Sci. § A 10 (1915) 185–186.

west from Baguio, elevation, 3,500 feet (about 1,066 meters). An unconformity probably exists near this locality.

As von Drasche pointed out, the great altitude of this coralline limestone is very striking, and the great amount of movement in northern Luzon since these Pliocene coralline limestones were deposited is very notable. Mount Mirador is about 1,200 meters in elevation and similar limestones are reported from Sagada at 1,372 meters. Smith [28] describes the limestone at Sagada as follows:

> The most extensive development of it is probably at Sagada, where we find it projecting from the soil and talus in great masses as shown in the photograph. The bedding planes, which can be distinctly made out even in the picture, dip about 20° southeast. On the weathered surfaces the stone is bluish gray, but on fresh fracture it is cream white to reddish. Plate IV, fig. 2, shows the characteristic spirelike forms produced by the dissolving action of the heavy rainfall of this region.
>
> A thin section of the rock shows innumerable fragments of the well-known Mio-Pliocene marine alga, *Lithothamnion ramosissimum* Reuss. This formation, therefore, is equivalent to the upper limestone in Cebu and many other parts of the Archipelago.

Apparently associated with these coralline limestones are some fine-grained tuffs which yielded a fine flora. Smith's description of the locality is as follows:

> At Sagada, where Father Staunton, of the Sagada Mission, has opened a quarry to secure material for his new church, is perhaps the best section of the tuff beds to be seen anywhere in the province. The face of the quarry is about 15 meters high and reveals the following beds:
>
> 1. Soil and loose material.
> 2. Tuff in heavy beds, 1.5 to 3 meters.
> 3. Yellow-stained shale, 0.5 meter.
> 4. Tuff in solid bed with varying texture, 18 meters.
> 5. Bluish black shaly-looking rock which is very fine-grained, 1 meter.
>
> * * * The dip is about 20° to the southeast. In the shaly portions are great numbers of leaf impressions.

Doctor Smith submitted these fossils to Mr. E. D. Merrill, botanist of the Bureau of Science, who described them as follows:

> The fossil remains, mostly remarkably clear leaf impressions, all, or nearly all, represent species still living in the Philippines at low and medium altitudes, and an examination of the material shows that the forest in the Bontoc locality was a typical mixed dipterocarp forest such as is found to-day in all parts of the Philippines, where primeval vegetation persists, from sea level to an altitude of about 800 meters. None of the species is found to-day within the limits of Bontoc subprovince, and very few of them are to be found in any part of Mountain Province. None of them is found above an altitude of approximately 800 meters, while the present altitude of the fossil-bearing strata is 1,500 meters.

[28] Smith, W. D., Philip. Journ. Sci. § A 10 (1915) 194.

Merrill identified the following living forms:

Dipterocarpaceæ: *Shorea polysperma, Shorea guiso, Shorea* sp., *Anisoptera thurifera.*
Lauraceæ: *Beilschmiedia cairocan, Phoebe sterculioides.*
Guttiferæ: *Calophyllum blancoi.*
Tiliaceæ: *Diplodiscus paniculatus.*
Menispermaceæ: *Anamirta cocculus.*
Cyperaceæ: *Mapania numilis.*

As Merrill points out, great elevations have taken place here since this tropical, low-altitude flora flourished on the present site of Sagada. These tuffs and their associated coralline limestones are probably equivalent to the Malumbang Pliocene. Apparently plants of the tropical regions have changed but little since the Pliocene, thus again evidencing the slowness of evolutionary change in these climes.

BANISILAN FORMATION

UPPER PLIOCENE

The following species were collected from the Banisilan formation by Graham B. Moody at his locality 424 which he described as being 1 mile east of Matinao, ⅝ mile west of Malitabug River, Cotabato, Mindanao.

List of species from Moody's locality 424.

GASTROPODA

Calliostoma sp.
Cancellaria oblonga Sowerby.
Capulus sp.
Cerithidea sp.
Conus sp., large.
Conus lividus Hwass.
Conus insculptus Kiener.
Cypraea erosa Linnæus.
Cypraea sp.
Distortio clathrata Lamarck.
Dolium sp.
Eulima sp.
Murex cf. *pliciferas* Sowerby.
Nassa crenulata Bruguiere.
Nassa sp.
Natica albumen Lamarck.
Natica mamilla Lamarck.
Natica spadicea Reeve.
Pustularia nucleus Linnæus.
Ranella subgranosa Beck.
Ranella sp.
Sigaretus eximius Reeve.
Triton clavator Lamarck.
Turris flavidula Lamarck var. *sonde* K. Martin.
Terebra sp.

PELECYPODA

Arca cf. *barbata* Linnæus.
Arca cornea Reeve.
Cardita antiquata Linnæus.
Cardita pica Reeve.
Chama sp.
Cardium unicolor Sowerby.
Chione sp.
Corbula sp.
Glycimeris angulatus Lamarck.
Leiconcha trimaculata (Desh.).
Lima sp.
Lucina sp.
Macoma nobilis Hanley.
Ostrea sp. a.
Ostrea sp. b.
Pecten squamosa Gmelin.
Pecten sp.
Spondylus sp.

COELENTERATA, ETC.

Echinoid spine.
Flabellum cf. *australe* Moseley.
Balanophyllia sp.
Cycloseris sp.
Three other coralline forms.
Vermes sp.

All the forms specifically identified are Recent species. The two forms *Flabellum* cf. *australe* Moseley and *Balanophyllia* also occur in Moody's locality 314, Humayan River, between Waloe and Loreto, Agusan Valley, Agusan Province, where they are associated with the following:

Cassis sp.
Cyclonassa elegans Kiener.
Nassa globosa Quoy.
Nassa crenulata Lamarck.
Nassa canaliculata Lamarck.
Cerithium jonkeri K. Martin.
Turritella terebra Lamarck.
Turris carinata Gray.
Arca ferruginea Reeve.
Paphia striata Chemnitz.

The form *Flabellum* cf. *australe* Moseley is identical with the species listed by Warren D. Smith from near Aroroy, on the west side of Aroroy Bay, Masbate, Bureau of Science locality F907, where it has a similar association as indicated above. The *Ballonophyllia* may be an extinct species, and the writer regards the association of these forms with similar assemblages of Gastropoda and Pelecypoda as not merely adventitious but indicative of essential synchrony. In other words, the Banisilan formation is equivalent to the beds exposed at Aroroy and the nearly horizontal beds at Moody's locality 314 in Agusan Valley. The latter are probably equivalent to beds referred to the Pliocene by Martin. Martin [29] listed Mindanao fossils as follows:

1. Left bank of Agusan River at Tagasáp.

Latirus madiunensis Mart. P.
Murex microphyllus Lam. M; L.
Ranella raninoides Mart. M.
Ranella gyrina Linn. L.
Turritella terebra Lam. Q; L.

2. Agusan River between Pagasap and Libuton.

Turritella terebra Lam. Q; L.
Venus squamosa Lam. P; L.

3. Maasin on the Agusan.

Conus insculptus Kien. M; L.
Turricula bataviana Mart. P.
Murex verbeeki Mart. P.
Natica mamilla Lam. M; L.

4. Salac y Maputi River.

Murex verbeeki Mart. P.
Strombus isabella Lam. Q; L.
Natica mamilla Lam. M; L.
Arca granosa Linn. P; L.
Clementia papyracea Gray. M; P; L.
Corbula scaphoides Hinds. M; P; L.

5. Zamboanga, River bank 2.5 miles north of Zamboanga, upper stratum.

Murex capucinus Lam. L.

[29] Martin, K., Concerning Tertiary fossils in the Philippines, English translation, Annual Rep. U. S. Geol. Survey 21 [3] (1899–1900) 619, 622, 623.

Concerning these species, he states his opinion, on pages 622 and 623:

> As for Mindanao, it can not be demonstrated from specimens which have been investigated that Miocene strata occur there, for I have but a single species, *Ranella raninoides* Mart., which is known only in the Miocene. On the other hand, it is clear that there are upper Tertiary beds along the Agusan River. If it were permissible to assume that all the fossils of the list given above originated in equivalent beds, and their state of preservation makes this probable, there would be in all 10 species, 6 of them, or 60 per cent, still living; 4 species occur in the Miocene and the same number in the Pliocene; but of these last three are known only from the Pliocene. These are *Latirus madiunensis* Mart., *Turricula bataviana* Mart., and *Murex verbeeki* Mart. All this argues the occurrence of the Pliocene on the Agusan River, and in harmony with this indication is the exceedingly fresh appearance of the fossils at hand.
>
> The same age finally may be ascribed to the fossils from the river Salac y Maputi in Mindanao; for although of the 6 species determined from this locality no fewer than 5 belong to the present fauna, yet of these latter 4 reach back to the Miocene and Pliocene and a single species, *Murex verbeeki* Mart., is known only in the Pliocene. Of the deposit at Zamboanga nothing definite can be said as yet on the strength of the solitary fossil *Murex capucinus* Lam.
>
> To the age determinations of Philippine fossils it is proper to add that their state of preservation resembles that of the Javanese fossils to a very remarkable extent—to such a degree, indeed, that the specimens from the two regions might easily be confounded. The same statement is true of the tuffs and marls in which they were embedded, and this accords with the fact that the younger massive rocks of the Philippines show an extraordinary likeness to those of the East Indian Archipelago.

The writer is in entire agreement with Martin's assignment of the Agusan beds to the Piocene and their analogue, the Banisilan formation, as well. The descriptions of Moody and Smith of the stratigraphic relations of the tuffaceous sandstones at Banisilan yielding the above fauna to the conformably underlying coralline limestone indicate that the Banisilan is upper Pliocene, since the coralline limestone is largely composed of corals characteristic of the Malumbang formation of Pliocene age.

Percentages given in Martin's statement above are calculated on a total of ten species from four different localities, and the number of forms is too small to be truly significant. *Turricula bataviana* Martin occurs at Bureau of Science locality F1054 near San Rafael, Agusan River, where it is associated with a fauna containing at least from 90 to 95 per cent Recent species. Without going into great detail, the writer's judgment concerning the age of this fauna is strongly influenced by a recent study made upon a fauna obtained from the Vigo group of Miocene age which contained an astonishingly large number of Recent

forms. The conclusions given in this paper are that the evolution of Gastropoda and Pelecypoda in the Tropics is far slower than in the Temperate Zones and hence a different percentage scale in the Tertiary must be applied in evaluating the Miocene, Pliocene, and Pleistocene of the Torrid Zone.

PLEISTOCENE

The beautiful Pleistocene limestones exposed in the end of the northwestern peninsula of Leyte offer an exceptional opportunity for the study of the conditions of formation of coralline limestone and allied problems. A cursory examination of these beds seems to indicate that most of the coral species still flourish in the neighboring waters. There are several marine terraces which denote successive uplifts, and each is covered by a thick deposit of coralline limestone. The underlying shales and sandstones of the Vigo group are exposed in a few places in the vicinity, and the unconformity between these beds and the overlying Pleistocene limestone is well marked. The same relation exists between the horizontal Pleistocene deposits and the well-folded Malumbang coralline limestones and interbedded marls at a point about half a mile south of Baliti, a small barrio (village) on the west coast of Leyte. Likewise, along the road on the west side of Cebu from Barili to Alegria, may be seen beautiful exposures which clearly indicate a great time interval between the Pleistocene and the Malumbang Pliocene, thus negativing Becker's [30] tentative idea that—

> Ever since the later Miocene there has been a continuous, very slow, rise of the island [Cebu] and extension of its land area, raising above water successively Upper Miocene, Pliocene, and Pleistocene beds, the total uplift amounting to over 2,000 feet.

Cebu Island has had a much more complicated history.

Nearly all the large islands show distinct terracing in places, but attempts to correlate these terraces from island to island will lead to failure, since there are many evidences of Pleistocene and Recent differential movements. These Pleistocene terraces, as a rule, are mantled by coralline limestone with which is associated a characteristic molluscan fauna such as is illustrated on Plate 15. Practically all of these Pleistocene species have representatives living to-day in these tropic seas.

Much work remains to be done upon the paleontology of the Philippines. Special effort should be made to search the older rocks more thoroughly for Paleozoic and Mesozoic fossils, and

[30] Becker, G. F., Annual Rep. U. S. Geol. Survey 21 (1901) 555.

far larger collections from the Tertiary should be made than are now available. Especial attention should be paid to the study of the Tertiary, Pleistocene, and Recent corals in this inviting field for research. The lack of well-authenticated vertebrate fossils is noteworthy; and any remains of vertebrates, such as those belonging to the horse and elephant families, would be very valuable in fixing in a more definite manner the tentative age correlations now set forth. Careful studies of the distribution of plants and animals such as Mr. E. D. Merrill, director and botanist of the Bureau of Science, and Mr. R. C. McGregor, ornithologist of the same institution, are now carrying on in their respective lines will greatly aid in checking conclusions concerning the geology, paleontology, and paleogeography of the Philippines.

LOCALITIES

Descriptions of localities to which brief reference will be made in explanation of plates are given below:

Locality 1x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, west side of Ragay Gulf; 2.75 kilometers northwest of Bureau of Lands bench mark No. 1, in coarse sandstone (coral and shell sand) dipping 12° south, strike north 50° west. Collectors, E. W. McDaniel and Roy E. Dickerson.

Locality 2x.—Philippine Islands, Luzon, Tayabas; 600 meters upstream from Bureau of Lands bench mark No. 1 (Bahay oil well No. 1) on northeast bank of Bahay River in a 17-meter cliff of yellow sandstone and bluish clayey sandstone disturbed by minor faulting. Collector, Roy E. Dickerson.

Locality 3x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, west shore of Ragay Gulf, Bahay River; upstream 800 meters from Bureau of Lands bench mark No. 1 (Bahay Oil Co. well No. 1) on southwest bank of stream in a stiff dark gray shale. August 25, 1919. Collectors, Roy E. Dickerson and Mark Fuken.

Locality 4x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, west side of Ragay Gulf, Bahay River; 320 meters east of mouth of Apad Creek in road cut 20 meters above the river in yellow sandstone about 17 meters stratigraphically above the brackish water fauna in the lignitic strata of locality 5. Collectors, Roy E. Dickerson and Mark Fuken.

Locality 5x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, west side of Ragay Gulf, Bahay River; 300 meters east of the mouth of Apad Creek in lignitic gray sandstone which was deposited in brackish water. Collector, Roy E. Dickerson.

Locality 6x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, Bahay-Apad Creek; 2.5 kilometers from mouth in large bowlders from Malumbang formation. September 1, 1919. Collector, Roy E. Dickerson.

Locality 7x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, Banco; 33 meters west of house on ridge between Maalat and

Canibo Creeks in a cream-colored yellow clay, a member of the Canguinsa formation. September 4, 1919. Collector, Roy E. Dickerson.

Locality 9x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, Dumalog Creek; about 8 kilometers northwest of San Narciso, 1.2 kilometers downstream from Mulanay-San Narciso trail in uppermost Vigo just below Canguinsa sandstone in black shale. October 17, 1919. Collectors, Roy E. Dickerson and Mark Fuken.

Locality 10x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, Sili Creek; 0.4 kilometer southwest of Sili, in black shale. Vigo shale. October 28, 1919. Collector, Roy E. Dickerson.

Locality 11x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, on west bank of Sapa Tubig Binukot; 365 meters upstream from mouth of Sapa Yaknas. Canguinsa fossils in soft yellow sandstone. October 31, 1919. Collector, Roy E. Dickerson.

Locality 12x.—Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, southern end on Sapa Tubig Binukot (Amuguis River); 274 meters downstream from mouth of Sapa Yaknas in east bank in chalk. Collector, Roy E. Dickerson.

Locality 21x.—Philippine Islands, Leyte Island, west shore of Leyte Bay, Panaliizan Barrio; south 65° east of Panaliizan Hill, west of Tuctuc. Malumbang limestone, at about 200 meters elevation. February 3, 1920. Collector, Roy E. Dickerson.

BUREAU OF SCIENCE LOCALITIES

Locality F7.—Batan, Batan Island, Perseverancia claim, Albay Province. Shale. Collector, W. D. Smith, May, 1905. "Gray shale overlying the East Batan coal seam; contains *Vicarya callosa*, etc., and numerous species of *Corbula*."

Locality F17.—Sitio of Gotas, Sibuguey Peninsula, center, near Sibuguey River, Zamboanga Province, Mindanao. Fossils from coal measures, tunnel 14. Collector, F. A. Dalburg, May 2, 1920.

Locality F272.—Danao, Cebu Province, hill east of mines 233 meters. Upper limestone. Collector, W. D. Smith, February, 1906. "On south slope of Mount Mangilao near Danao. This locality is at the base of the upper limestone and at the summit of a lower limestone horizon. There is a marl below this which is apparently unfossiliferous. The fossils were picked up where they had already weathered out of the formation. Elevation about 200 meters above sea level."

Locality F290.—Philippine Islands, Cebu Province, Naga, Uling coal district. Fossils in Sapa Sibod on Alpaco road (Doña Margarita Roxas). Collector, F. A. Dalburg, his locality 8.

Locality F1054.—San Rafael, Agusan River, Agusan Province, Mindanao Island. Recent sandy shale. Collectors, Ickis and Goodman, 1908.

ILLUSTRATIONS

[The plates of Vigo and Malumbang fossils are from photographs made by Mr. E. Cortes, chief photographer, Bureau of Science, and retouched, by comparison with the specimens, by Mr. Pio Moskaira, chief of drafting section, division of mines, Bureau of Science.]

PLATE 1. MESOZOIC JURASSIC (?) RADIOLARIA

FIG. 1. Thin section of old "slate" of probable Jurassic age, containing Radiolaria; × 100.

2. Highly magnified portion of same thin section; × 200. After W. D. Smith, Philip. Journ. Sci. § A 8 (1913).

PLATE 2. VIGO GROUP, MIOCENE

All fossils figured on this plate were collected from Vigo group, Canguinsa formation, Bondoc Peninsula, Tayabas Province, Luzon.

FIG. 1a. *Architectonica pictum* (Philippi), top view; × 2. Locality 4x. This species is living in Philippine seas at present.

1b. *Architectonica pictum* (Philippi), bottom view of a small specimen; × 8/5. Locality 3x.

2. *Actaeon reticulatus* K. Martin; × 8/5. Locality 3x. An extinct form.

3. *Cancellaria crenifera* Sowerby; × 4/3. Locality 2x. A living species.

4. *Cerithium* sp. nov. (?); × 1. Locality 3x.

5. *Cerithium* sp.; × 2. Locality 4x.

6. *Cerithium bandongensis* K. Martin; × 2. Locality 4x. The type of this species was collected from upper Miocene beds near Bandong, Java. It is probably a good guide fossil for the Vigo group.

7. *Cerithium jenkinsi* K. Martin; × 8/6. Locality 3x. This is an extinct species which is possibly characteristic of the Vigo group.

8. *Cerithium moniliferum* Kiener; × 5/6. Locality 3x. This species is found on the Philippine beaches of the present.

9a. *Cerithium herklotsi* K. Martin; × 1. Locality 3x. This figure illustrates a mature individual whose body whorl is almost smooth in contrast with the upper whorls of the spire.

9b. *Cerithium herklotsi* K. Martin; × 8/6. Locality 3x. In a young individual the nodose body whorl is a youthful character, as our collections contain a striking series which directly connects this development stage with the mature individual.

10. *Cerithidea* cf. *quadrata* Sowerby; × 8/9. Locality 11x.

11. *Conus ornatissimus* K. Martin; × 1. Locality 3x, Bahay River, Bondoc Peninsula, Luzon. This beautiful extinct species is probably a guide fossil of the Vigo Miocene.

12. *Conus lividus* Hwass; × 1. Locality 2x. This beautiful cone is still living in Philippine waters.

13. *Conus striatellus* Jenkins; $\times \frac{4}{5}$. Locality 9x, Dumalog Creek, Canguinsa formation.
14. *Conus loroisii* Kiener; $\times \frac{4}{5}$. Locality 5x, Bahay River. This living species was found in a lignitic sandstone bed associated with *Ostrea* sp., *Cerithium* sp., amber, and fossil wood. But a single specimen was found.
15. *Conus hardi* K. Martin; $\times \frac{5}{6}$. Locality 9x.
16. *Columbella bandongensis* K. Martin; $\times 1$. Locality 3x.
17. *Delphinula reeviana* Hinds; $\times 2$. Locality 4x.
18a. *Delphinula* sp. b, back view; $\times 2$. Locality 4x.
18b. *Delphinula* sp. b, front view; $\times 2$. Locality 4x.
19. *Pyrula (Melongena) galeodes* Lamarck; $\times \frac{4}{5}$. Locality 290.
20. *Distortio clathrata* Lamarck; $\times \frac{5}{6}$. Locality 3x. A living species.
21. *Eburna ambulacrum* Sowerby; $\times \frac{4}{5}$. Locality 4x.
22. *Epitonium* sp.; $\times 1$. Locality 11x.
23. *Ficus reticulatus* (Lamarck); $\times \frac{5}{6}$. Locality 11x. This is a beautiful species, which is living in the China Sea.

PLATE 3. VIGO GROUP, MIOCENE

FIG. 1. *Fusus verbeeki* K. Martin; $\times \frac{7}{8}$. Bureau of Science locality F290, Uling district, Cebu, Sibod Gulch, Alpaco road; collector, F. A. Dalburg.
2. *Harpa articularis* Lamarck; $\times \frac{4}{5}$. Locality 11x.
3a. *Mitra javana* K. Martin; $\times 1$. Locality 3x. The outer lip of this specimen is somewhat broken, thus exposing the lirations on the inner lip unusually well. This form is probably restricted to the Vigo group.
3b. *Mitra javana* K. Martin; $\times \frac{5}{6}$. Locality 2x. A young individual.
3c. *Mitra javana* K. Martin; $\times \frac{4}{5}$. Locality 4x. An unusually slender form of this species.
4. *Mitra junghuhni* (?) K. Martin; $\times \frac{5}{6}$. Locality 3x.
5. *Mitra bucciniformis* K. Martin; $\times 2$. Locality 4x.
6. *Mitra* sp.; $\times 2$. Bureau of Science locality F290.
7. *Mangelia balteata* Reeve; $\times 2$. Locality 4x.
8. *Murex endivia* Lamarck; $\times 1$. Locality 3x.
9. *Murex* sp.; $\times \frac{5}{8}$. Locality 2x.
10. *Murex* (?) sp.; $\times \frac{7}{8}$. Bureau of Science locality F290.
11a. *Marginella simplicissima* K. Martin; $\times \frac{5}{6}$. Back view. Locality 4x.
11b. *Marginella simplicissima* K. Martin; $\times \frac{5}{6}$. Locality 4x.
12. *Nassa dispar* Adams; $\times 1$. Locality 3x. All the members of this genus thus far identified from the Philippine Miocene are living forms. *Nassa canaliculata*, *N. dispar*, and *N. crenulata* are three closely allied species whose variations are difficult to classify.
13. *Nassa canaliculata* Lamarck; $\times 1$. Locality 3x.
14a. *Nassa crenulata* Bruguiere; $\times 1$. Locality 3x.
14b. *Nassa crenulata* Bruguiere; $\times 2$. Locality 4x.
15a. *Nassa globosa minor* Quoy; $\times \frac{5}{6}$. Front view. Locality 3x.
15b. *Nassa globosa minor* Quoy; $\times \frac{5}{6}$. Locality 3x. *Nassa globosa minor*, *N. globosa leptospira*, *N. globosa thersites*, and *N. quadrasi* form a closely allied group.

16. *Nassa quadrasi* Hidalgo; × ⅘. Locality 3x.
17a. *Nassa thersites leptospira* (Bruguiere); × ⅘. Locality 3x.
17b. *Nassa thersites leptospira* (Bruguiere); × ⅘. Front view. Locality 3x.
18a. *Nassa thersites immersa* Carpenter; × ⅚. Back view. Locality 3x.
18b. *Nassa thersites immersa* Carpenter; × ⅚. Front view. Locality 3x.
19. *Nassa costellifera* A. Adams; × ⅚. Locality 11x.

PLATE 4. VIGO GROUP, MIOCENE

FIG. 1. *Natica albumen* Lamarck; × ⅞. Locality 2x.
2. *Natica* sp.; × ⅘. Locality 9x.
3a. *Natica spadicea* Reeve; × ⅚. Locality 2x.
3b. *Natica spadicea* Reeve; × ⅘. Locality 11x.
3c. *Natica spadicea* Reeve, operculum; × ⅚. Locality 11x.
4. *Natica lacernula* D'Orbigny; × ⅚. Locality 3x.
5. *Natica mamilla* Lamarck; × ⅚. Locality 2x.
6. *Natica cumingiana* Recluz. Locality 11x.
7. *Nerita funiculata* Reeve; × ⅚. Locality 2x.
8. *Neritina* cf. *squarrosa* Recluz; × ⅚. Locality 5x.
9. *Oliva* cf. *utriculus* Gmelin; × ⅚. Locality 3x.
10. *Phos roseatus* Hinds; × ⅚. Locality 3x.
11. *Pyrula gigas* K. Martin; × ⅘. Locality 5x.
12. *Pyramidella* sp. Locality 4x.
13a. *Ranella subgranosa* Beck; × ⅞. Bureau of Science locality F290. Sibod Creek, Uling district, Cebu. The lower tip of the canal is broken off, giving the form a more robust appearance than the Recent specimens in the Quadras collection.
13b. *Ranella subgranosa* Beck; × ⅚. Locality 2x.
14. *Ranella tuberculata* Broderip; × ⅞. Locality 2x.
15. *Ricinula spectrum* Reeve; × 2. Locality 4x.
16. *Rimella agusana* (Smith); × ⅘. Locality 10x, Vigo shale, Sili Creek, at seepage, southern end of Bondoc Peninsula, Tayabas Province, Luzon. This species was originally described as a *Turris*, but better material necessitates its reference to another genus.

PLATE 5. VIGO GROUP, MIOCENE

FIG. 1a. *Rostellaria fusus* Linnæus; × ⅘. Locality 4x.
1b. *Rostellaria fusus* Linnæus; × ⅘. Locality 4x. The upper whorls of the spire are decorated in contrast to the smooth whorls below.
2. *Rostellaria crispata* Kiener; × 1. Locality 3x.
3. *Strombus canarium* (Linnæus); × ⅞. Bureau of Science locality F290.
4. *Strombus gendinganensis* K. Martin; × 1. Locality 3x.
5. *Strombus* sp. a; × ⅘. Locality 4x.
6. *Strombus swainsoni* Reeve; × ⅚. Locality 2x.
7. *Strombus dentatus sonde* (Lamarck) K. Martin; × 1. Locality 3x.
8. *Strombus* cf. *fusus* K. Martin; × ⅘. Locality 9x.
9. *Turris flavidula* Lamarck; × ⅞. Locality 2x.

10. *Turris garnonsi* Reeve; × 1. Locality 3x.
11. *Turris deshayesi* (Doumet); × ⅘. Locality 2x.
12a. *Turris carinata woodwardi* K. Martin; × 1. Locality 3x.
12b. *Turris carinata woodwardi* K. Martin; × ⅚. Locality 2x. This is a mature form whose body whorl is more robust than that of the immature individual shown as fig. 12a.
13. *Turris marmora* (Lamarck); × ⅘. Locality 4x.
14. *Terebra bicincta* K. Martin; × ⅘. Locality 2x. This species is probably characteristic of the Vigo group.
15. *Terebra javana* K. Martin; × ⅘. Locality 2x. This is an extinct Vigo form.
16. *Triton pfeifferianum* Reeve; × 1. Locality 2x.
17. *Turbo* (?) sp.; × 2. Locality 4x.
18. *Tubonilla* sp.; × ⅘. Locality 2x.

PLATE 6. VIGO GROUP, MIOCENE

FIG. 1a. *Vicarya callosa* Jenkins; × ¾. Bureau of Science locality F17. Tunnel No. 14, Sibuguey Peninsula, Mindanao; collector, F. A. Dalburg. This "finger post" of the Malayan Miocene is found at numerous localities in the Philippines, and as a rule the strata containing specimens are associated with the coal seams or lignitic strata.

1b. *Vicarya callosa* Jenkins; × ⅘. Bureau of Science locality 7. Gray shale overlying the East Batan coal seam in the Perseverancia claim, Batan Island; collector, F. A. Dalburg. This picture illustrates the size and peculiar character of the callosity as developed upon a mature specimen.

1c. *Vicarya callosa* Jenkins; × ⅘. Bureau of Science locality 7. Showing spire whorls of a mature specimen.

2. *Voluta innexa* Reeve; × ¾. Bureau of Science locality 272, Cebu.
3. *Arca ferruginea* Reeve; × ⅚. Locality 4x.
4. *Arca granosa* Linnæus; × ⅚. Locality 3x.
5. *Arca tenebrica* Reeve; × 2. Locality 5x.
6. *Arca* sp.; × 2. Locality 2x.
7. *Cardium elongatum* Bruguiere; × ⅚. Locality 11x.
8a. *Cardium unicolor* Sowerby; × ⅚. Locality 11x.
8b. *Cardium unicolor* Sowerby; × ⅚. Locality 11x.
9a. *Cardium donaciformis* Cuming; × ⅘. Locality 2x.
9b. *Cardium donaciformis* Cuming; × ⅘. Locality 2x.
10. *Cardita antiquata* Linnæus; × ⅚. Locality 11x.
11. *Corbula socialis* K. Martin; × ⅚. Locality 3x.
12a. *Corbula* sp.; × ⅘. Locality 3x.
12b. *Corbula* sp.; × ⅘. Locality 3x.
13a. *Corbula scaphoides* Hinds; × ⅚. Locality 3x. View of right valve of small specimen.
13b. *Corbula scaphoides* Hinds; × ⅘. Locality 3x. View of left valve, which is much smaller than right.
14. *Dosinia cretacea* Philippi; × ⅘. Locality 9x. Dumalog Creek, Bondoc Peninsula, Tayabas Province, Luzon.
15a. *Glycimeris viteus* (Lamarck); × ⅚. Locality 11x. View showing hinge.
15b. *Glycimeris viteus* (Lamarck); × ⅚. Locality 11x.

16a. *Lucina* cf. *argentia* Reeve; × 2. Locality 11x. This form is semi-transparent and the ribbing corresponds to Reeve's species, but the shape is somewhat different.
16b. *Lucina* cf. *argentia* Reeve; × 2. Locality 11x.
17. *Ostrea* sp.; × ⅝. Locality 5x.

PLATE 7. VIGO GROUP, MIOCENE

FIG. 1. *Pecten (Pleuronectia) pleuronectia* Linnæus; × ⅝. Locality 4x.
2a. *Placuna placenta* Linnæus; × ⅔. Locality 4x.
2b. *Placuna placenta* Linnæus; × ⅔. Locality 4x.
3. *Paphia textrix* Deshayes; × ¾. Locality 2x.
4. *Spisula* sp.; × 2. Locality 11x.
5. *Vermetus javanus* (?) K. Martin; × ⅘. Locality 11x.

PLATE 8. FORAMINIFERA FROM CEBU

FIG. 1. *Alveolinella;* × 10. Old Alpaco mines, Cebu; locality F273.
2. *Orbitolites;* × 10. Locality F273.
3. *Operculina costata* d'Orbigny; × 10. Minanga River, Cebu, F277.
4. *Operculina costata* var. *tuberculata* Douvillé; × 10. Old Alpaco mines, Cebu, F273.
5. *Cycloclypeus communis* Martin; × 10. Minanga River, Cebu, F277.
6. *Heterostegina;* × 10. Barrio of Mesaba, Cebu, F272.
7. *Lepidocyclina insulæ-natalis* Jones and Chapman; × 10. Guila-Guila, Cebu, F278. After a slide prepared by Warren D. Smith.

PLATE 9. VIGO GROUP, MIOCENE

Lepidocyclina limestone from Cebu (copied from Yabe). The fossils figured were collected at Puting Bato, Cebu, near Cebu City, from limestone.

FIG. 1b. *Lepidocyclina (Eulepidina) formosa* Schlumberger.
1c. *Lepidocyclina (Eulepidina) gibbosa* Yabe.
1g. *Spiroclypeus* cf. *margaritatus* Schlumberger, in oblique section.
1h. *Cycloclypeus* or *Heterostegina*, in transverse section; × 7.
2b. *Lepidocyclina (Eulepidina) formosa* Schlumberger.
2h. *Cycloclypeus* or *Heterostegina*, both in transverse section; × 15.

PLATE 10. VIGO GROUP, MIOCENE

Lepidocyclina limestone from Cebu (copied from Yabe).

FIG. 1b. *Lepidocyclina (Eulepidina) formosa* Schlumberger.
1g. *Spiroclypeus* cf. *margaritatus* Schlumberger; × 7. In oblique section.
2. *Lepidocyclina (Eulepidina) monstrosa* Yabe; × 7. In tangential section.
3a. *Lepidocyclina (Eulepidina) monstrosa* Yabe. In tangential section.
3b. *Lepidocyclina (Eulepidina) formosa* Schlumberger; × 7. One in transverse section through the nucleoconch, and the other in almost median section.

PLATE 11. MALUMBANG FORMATION, PLIOCENE

All the specimens figured on this plate, except *Chione chlorotica*, were collected from locality 1x, Malumbang formation, Bondoc Peninsula, Tayabas Province, Luzon.

FIG. 1a. *Leucosia* cf. *unidentata* de Haan; $\times \frac{4}{5}$. Ventral view.
1b. *Leucosia* cf. *unidentata* de Haan; $\times \frac{4}{5}$. Dorsal view.
2. *Conus ornatissimus* K. Martin; $\times \frac{9}{11}$. This is a form at least subspecifically different from the typical *C. ornatissimus* of Martin. The notable difference is the greater width of this Pliocene form.
3. *Cardita antiquata* Linnæus; $\times 1$. This form is very abundant in the Recent fauna of the Philippines.
4a. *Aspergillum annulosum* Deshayes; $\times \frac{4}{5}$. This very aberrant pelecypod has all the characters common to the Recent species which was originally described from the Vizcayan seas.
4b. *Aspergillum annulosum* Deshayes; $\times \frac{9}{11}$.
5. *Chione chlorotica* Philippi; $\times \frac{3}{4}$. Bureau of Science locality 1054, Agusan Valley, from Pliocene strata, probably equivalent to the Banisilan Pliocene.
6a. *Glycimeris multistriatus* (Deshayes); $\times \frac{4}{5}$. In view showing hinge characters. This species is still flourishing in Philippine waters.
6b. *Glycimeris multistriatus* (Deshayes); $\times \frac{4}{5}$.
7. *Lucina* cf. *borealis* (Linnæus); $\times \frac{2}{3}$. This species was collected from the Malumbang strata of Leyte, locality 21x. Reeve reports *L. borealis* from Manila Bay, but Hidalgo states that this species is not reported by any other Philippine collector.
8. *Metis* (?) sp.; $\times \frac{3}{4}$.
9. *Ostrea* sp.
10a. *Pecten leopardus* Reeve; $\times \frac{3}{4}$. Right valve.
10b. *Pecten leopardus* Reeve.
11a. *Pecten exaratus* K. Martin. Left valve.
11b. *Pecten exaratus* K. Martin. Right valve.

PLATE 12. MALUMBANG FORMATION, PLIOCENE

FIG. 1a. *Pecten naganumana* Yokoyama; $\times \frac{2}{3}$. This, the type of this species, was described by Dr. M. Yokoyama, of the Imperial University of Tokyo, from the Lower Musashino formation of probable upper Pliocene age.
1b. *Pecten naganumana* Yokoyama; $\times \frac{2}{3}$. Convex right valve.
2. *Spondylus* sp.
3. *Spondylus imperialis* Chemnitz; $\times \frac{5}{6}$.
4. *Venus squamosa* Lamarck; $\times \frac{5}{6}$. Bureau of Science locality 1054.
5. *Fungia* sp.; $\times \frac{7}{8}$. Bureau of Science locality.
6a. *Flabellum* cf. *australe* Moseley; $\times \frac{9}{11}$.
6b. *Flabellum* cf. *australe* Moseley; $\times \frac{9}{11}$.
7. *Leptoria* sp.; $\times \frac{3}{4}$. Locality 6x.

PLATE 13. MALUMBANG FORMATION, PLIOCENE

FIG. 1. *Goniastraea* sp.; $\times \frac{3}{4}$. Locality 6x.
2. *Acropora* (?) sp.; $\times \frac{2}{3}$. Locality 6x.
3a. *Clypeaster* sp. a; $\times \frac{4}{5}$. Locality 1x. Abactinal view.
3b. *Clypeaster* sp. a; $\times \frac{4}{5}$. Actinal view of specimen figured as 3a.
4. *Clypeaster* sp. b; $\times \frac{5}{6}$. Bureau of Science locality.
5a. *Schizaster subrhomboidalis* Herklots; $\times \frac{2}{3}$. Bureau of Science locality. Aboral view.
5b. *Schizaster subrhomboidalis* Herklots; $\times \frac{2}{3}$. Oral view of specimen figured as 5a.

Plate 14. Malumbang Formation, Pliocene

Fossil plants from Sagada, Mountain Province, Luzon. The figured specimens were identified by Mr. Elmer D. Merrill, of the Bureau of Science.

Fig. 1. *Beilschmiedia cairocan* Vidal. An endemic species of the Lauraceæ.
2. *Phoebe sterculioides* Merrill. An endemic species of the Lauraceæ.
3. *Anamirta cocculus* Wight and Arnott. An Indo-Malayan species of the Menispermaceæ.
4. *Shorea polysperma* Merrill. An endemic species of the Dipterocarpaceæ.

Plate 15. Pleistocene

Fossils from raised coral reefs near San Andres, Bondoc Peninsula, Tayabas Province. About one-half natural size (after Pratt and Smith).

Fig. 1. *Conus flavidus* Lamarck.
2. *Strombus* sp.
3. *Strombus* sp.
4. *Potamides* sp.
5. *Spondylus* sp.
6. *Telescopium telescopium* Linnæus.
8. *Trochus fenestratus* Gmelin.
9. *Crista pectinata* Linnæus.
10. *Cerithium nodulosum* Bruguiere.
11. *Circe pectinata* Linnæus.
12. *Potamides* sp. Youthful individual of the form shown in fig. 4.
13. *Arca cornea* Reeve.
14. *Strombus canarium* Linnæus.

Plate 16

Map of the Philippine Islands.

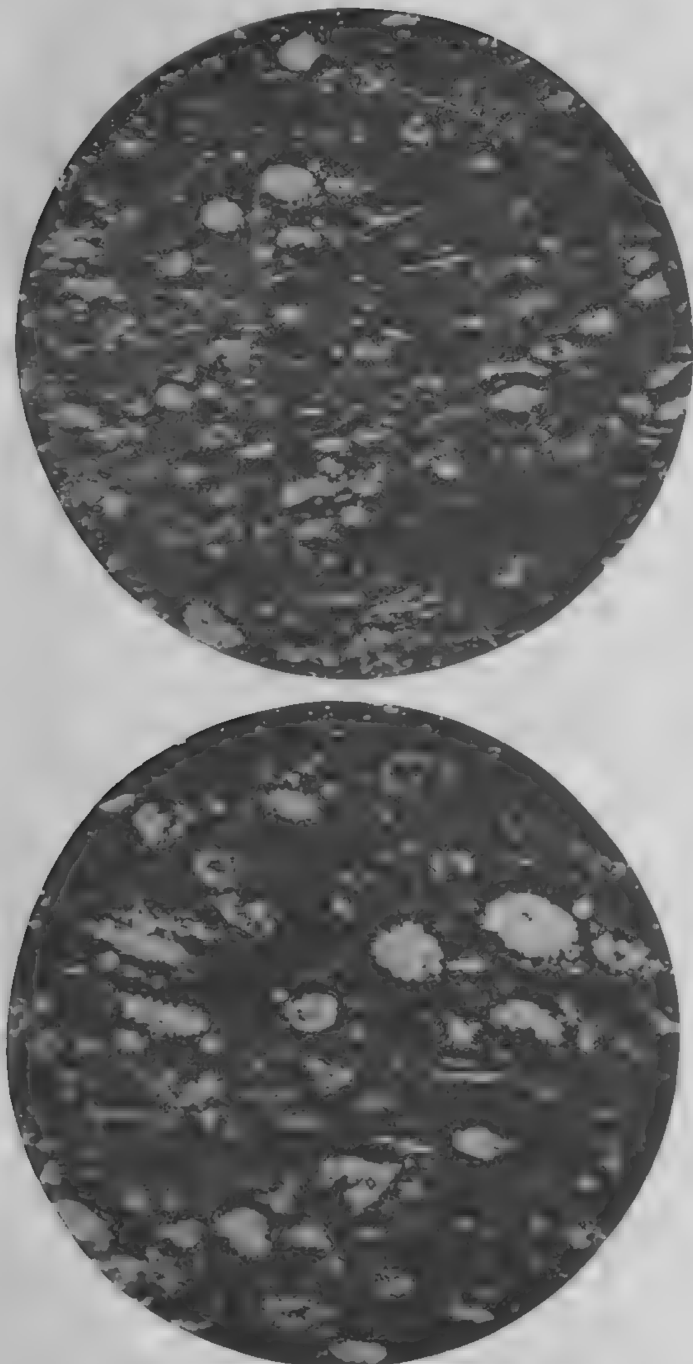

PLATE 1. MESOZOIC, JURASSIC (?) RADIOLARIA.

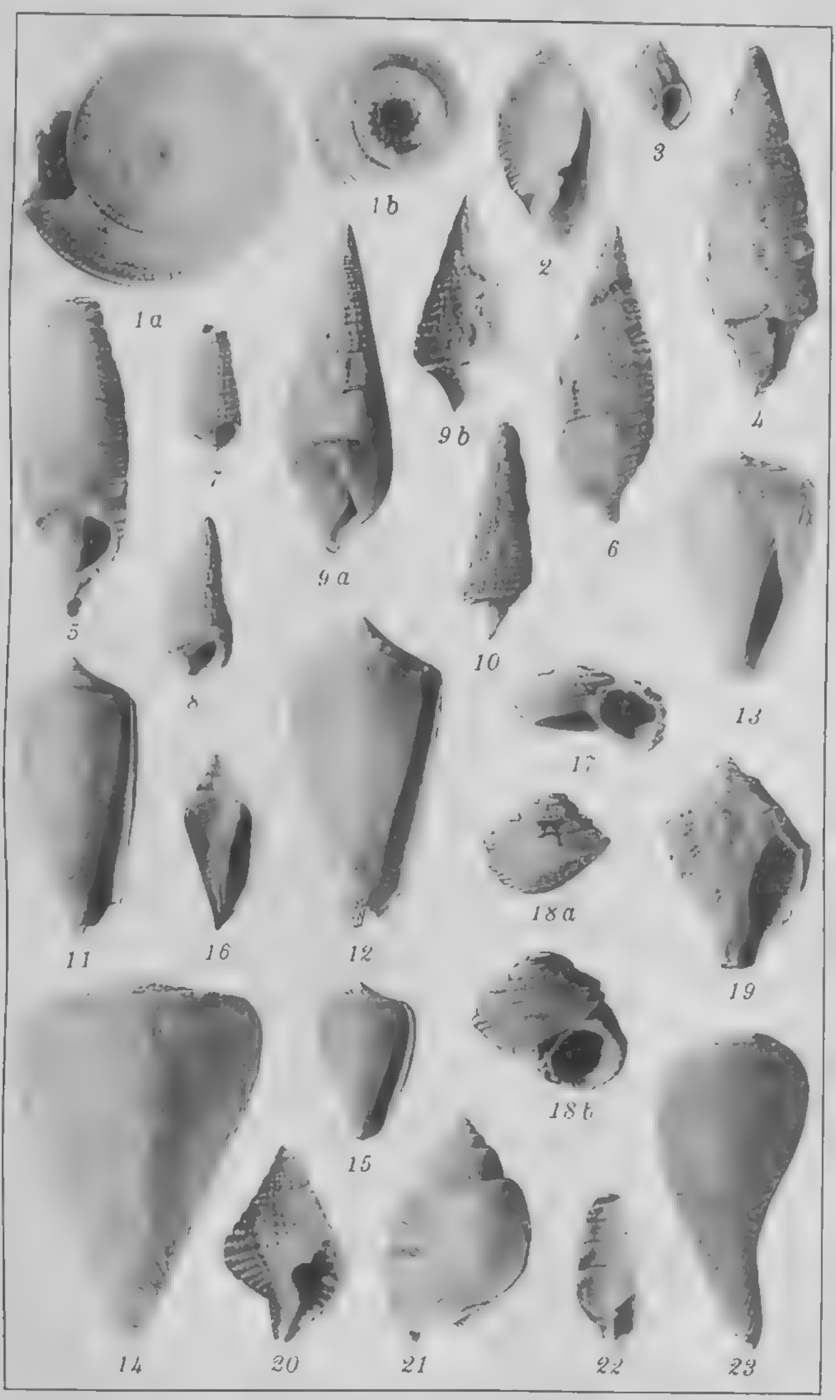

PLATE 2. VIGO GROUP, MIOCENE FOSSILS.

PLATE 3. VIGO GROUP, MIOCENE FOSSILS.

PLATE 4. VIGO GROUP. MIOCENE FOSSILS.

PLATE 5. VIGO GROUP, MIOCENE FOSSILS.

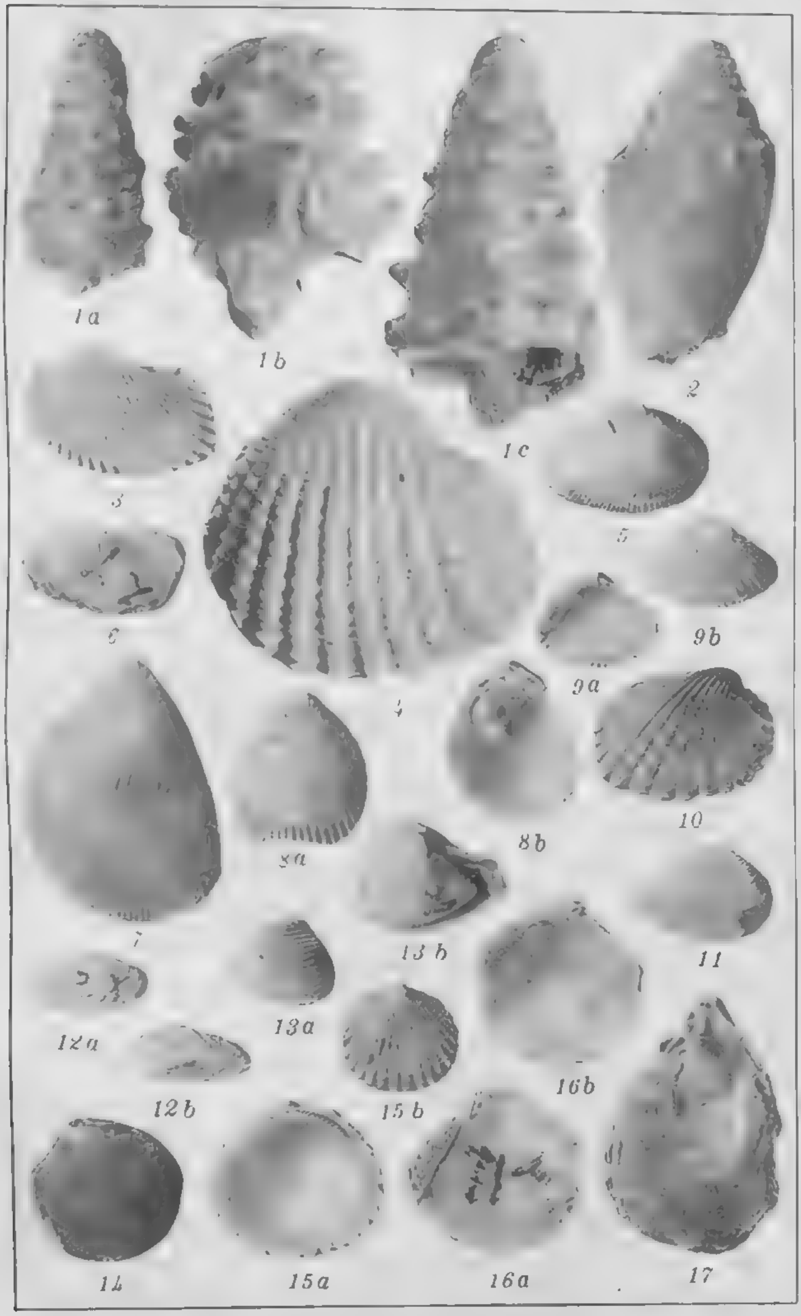

PLATE 6. VIGO GROUP, MIOCENE FOSSILS.

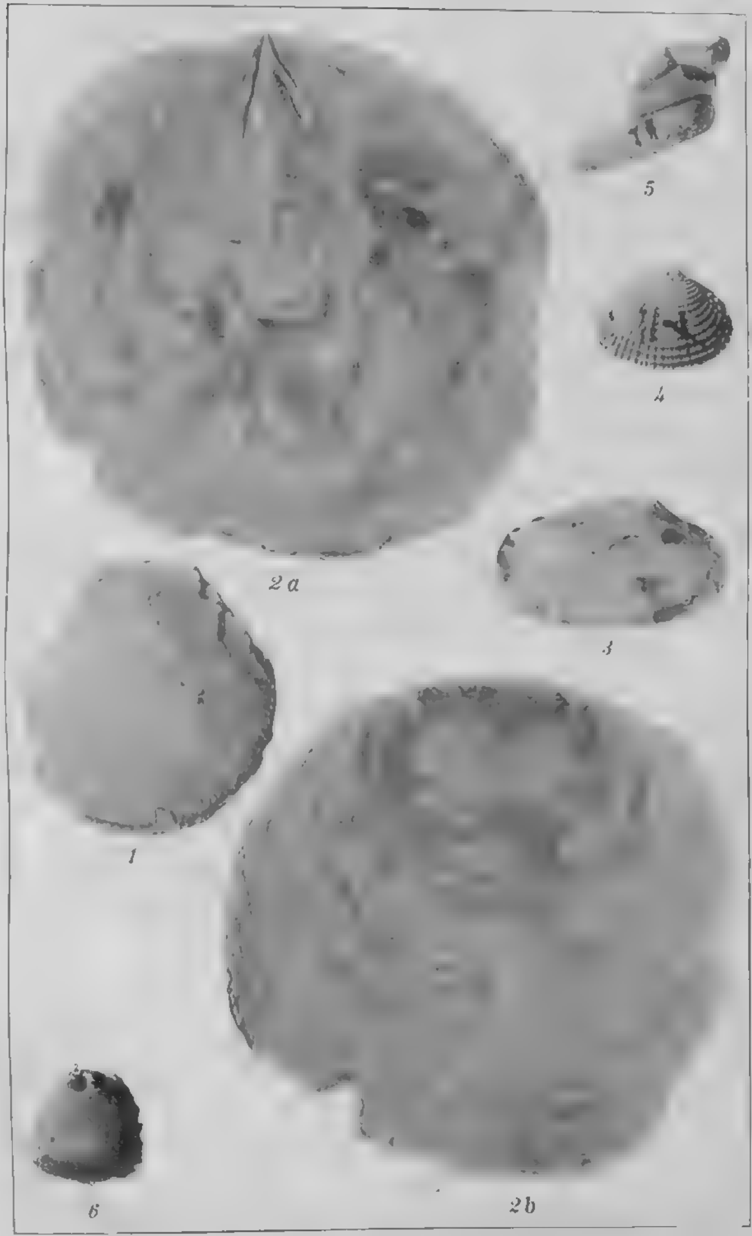

PLATE 7 VIGO GROUP, MIOCENE FOSSILS.

PLATE 8. FORAMINIFERA FROM CEBU.

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PLATE 9. VIGO GROUP, MIOCENE FOSSILS.

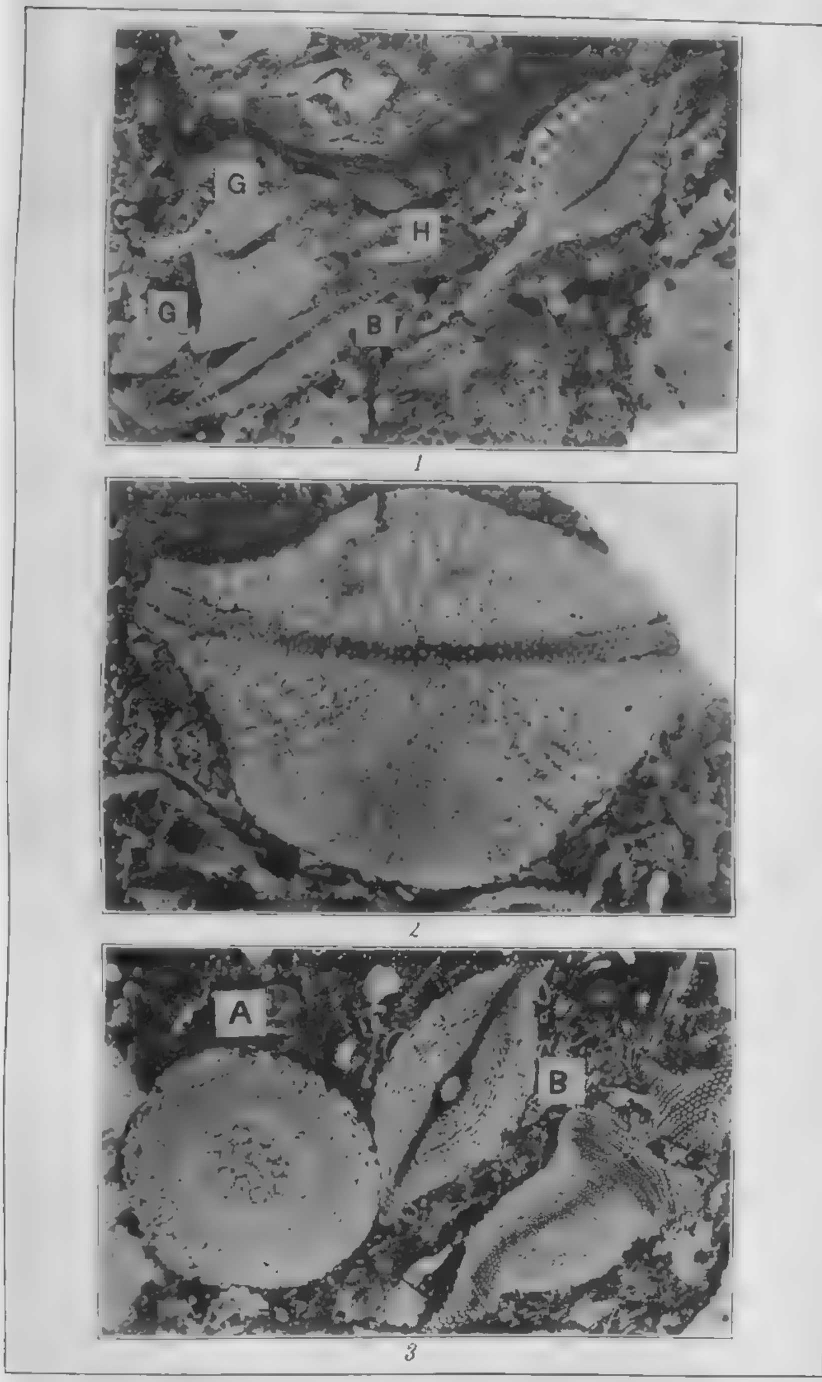

PLATE 10. VIGO GROUP, MIOCENE FOSSILS.

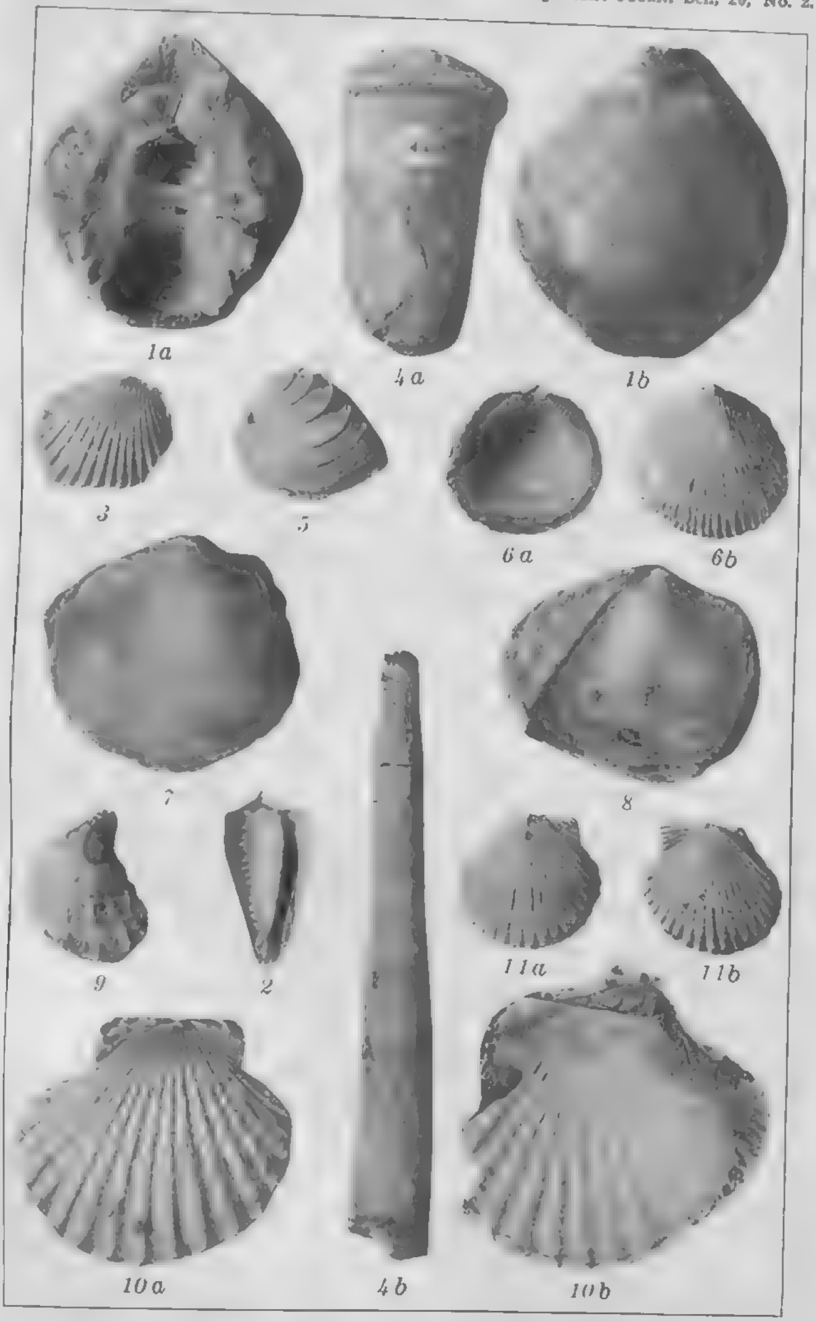

PLATE 11. MALUMBANG FORMATION, PLIOCENE FOSSILS.

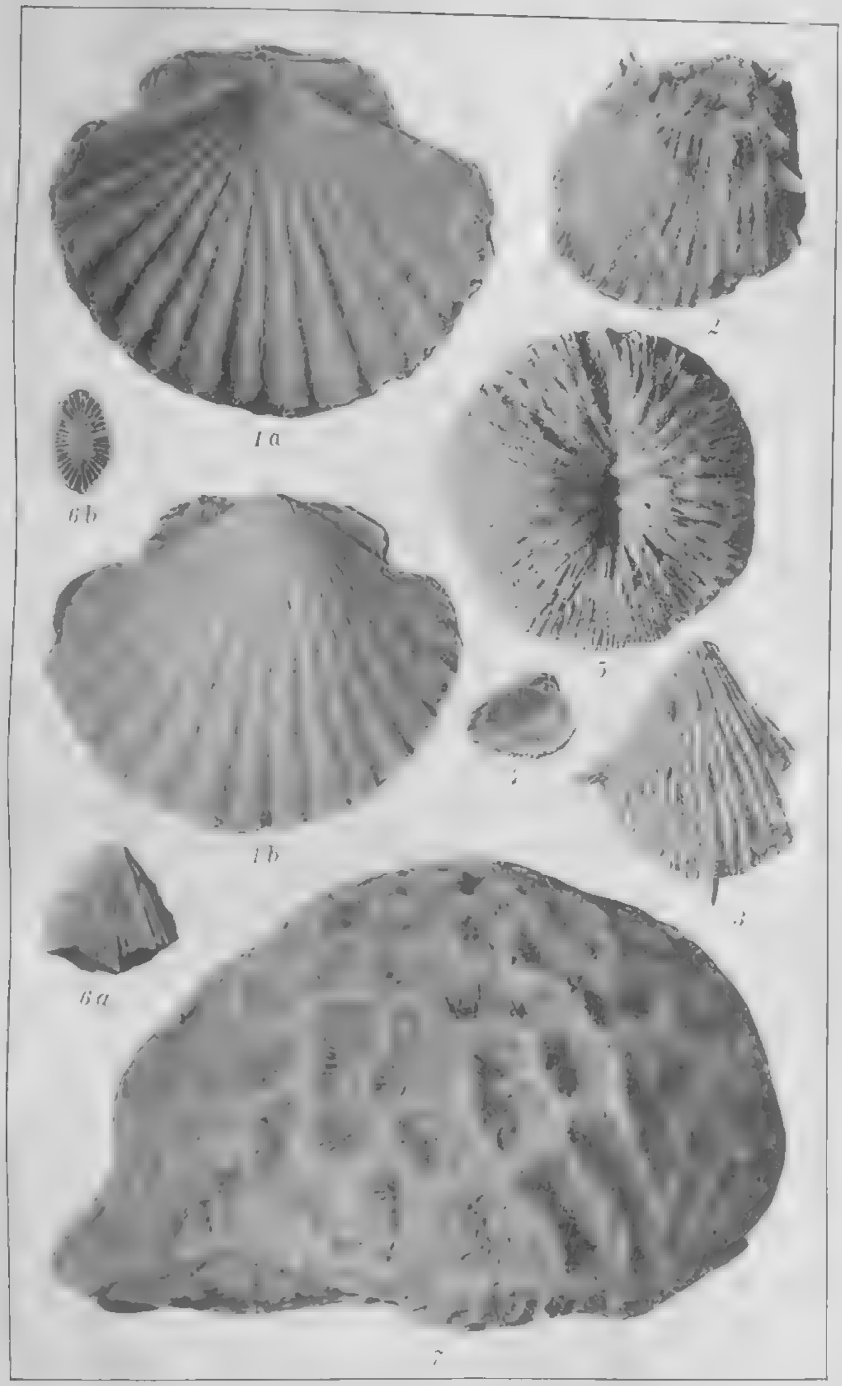

PLATE 12. MALUMBANG FORMATION, PLIOCENE FOSSILS.

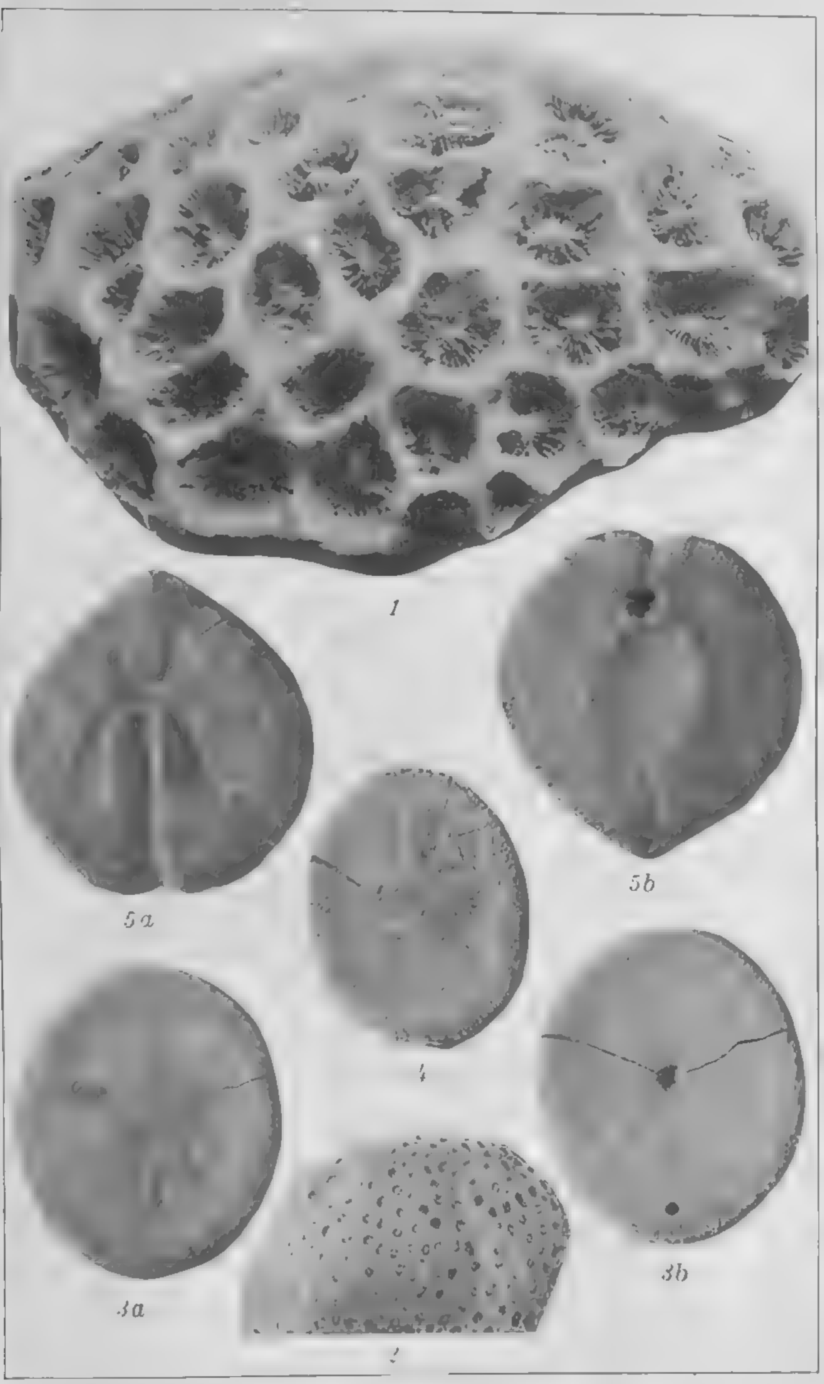

PLATE 13. MALUMBANG FORMATION, PLIOCENE FOSSILS.

PLATE 14. MALUMBANG FORMATION, PLIOCENE FOSSILS.

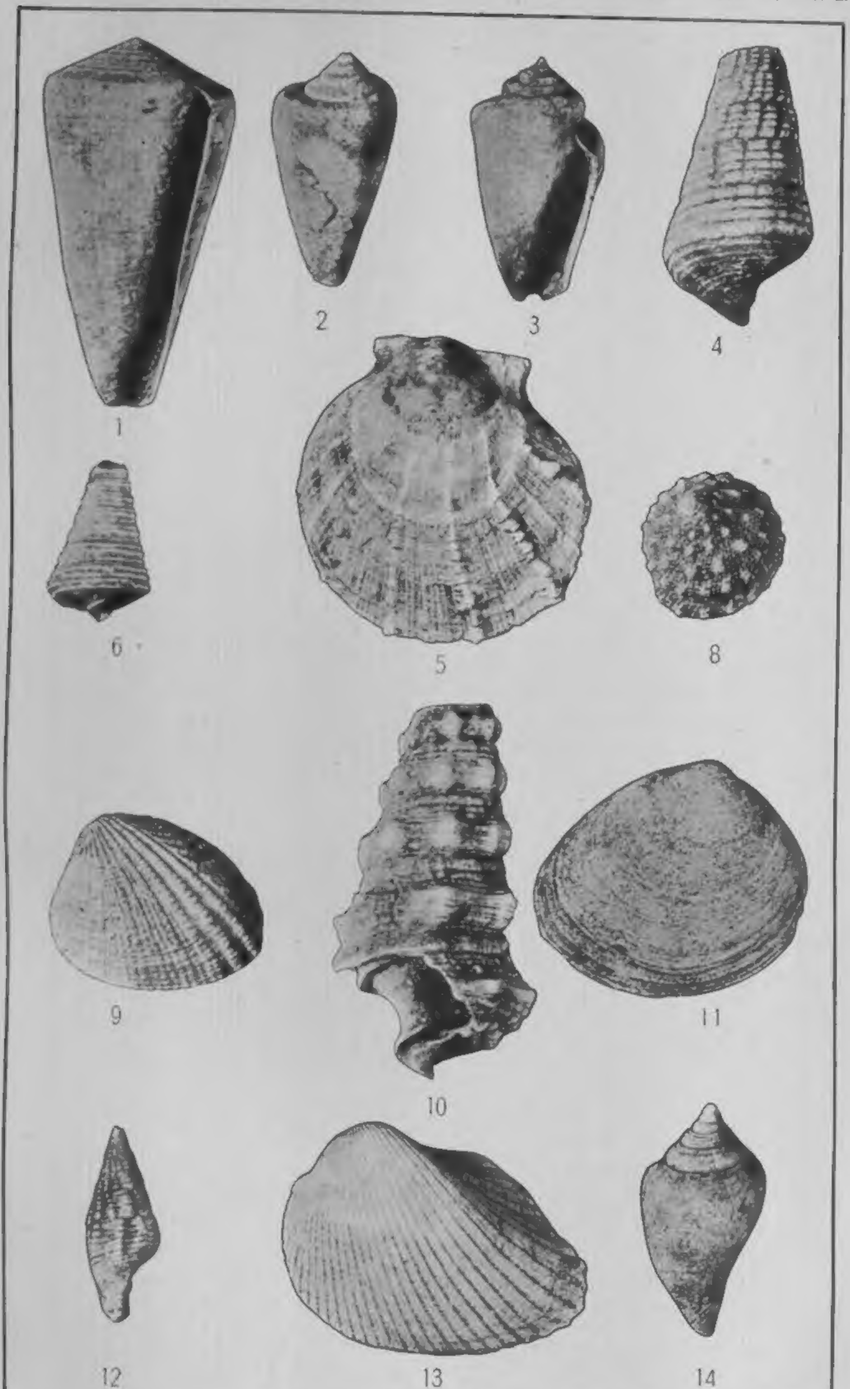

PLATE 15. PLEISTOCENE FOSSILS FROM BONDOC PENINSULA.

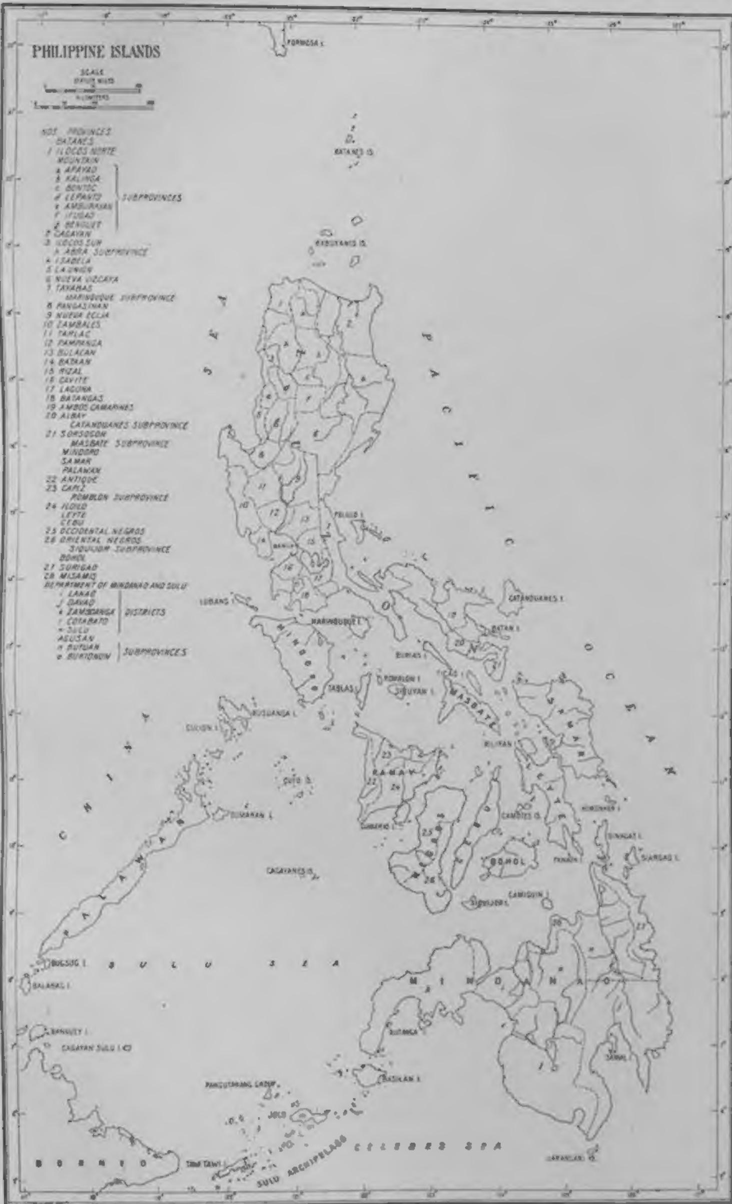

PLATE 16. THE PHILIPPINE ISLANDS.

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